The use of winery waste compost to establish cabbage (*Brassica oleracea* var*. capitata* L*.*) and Swiss chard (*Beta vulgaris* subsp*. cycla*) on sandy soil at Bien Donné experimental farm near Paarl in the Western Cape region

by

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DECLARATION

I, **Ncedo Goodwill Ndololwana**, declare that the contents of this thesis represent my own unaided work, and that the thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

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Signed   Date: November 2015

ABSTRACT

A study was carried out at Bien Donné Experimental Farm, near Paarl in the Western Cape Region (South Africa), to evaluate the performance of solid winery waste compost (WWC) and inorganic fertilizer (N:P:K, 2:3:4 (30) - 5g Zn%) on growth and yield of cabbage (*Brassica oleracea* var*. capitata* L*.*) and Swiss chard (*Beta vulgaris* subsp*. cycla*). The experimental plot was fertilized as per treatment with WWC (100% and 400% equivalent recommended fertilizer application using N as reference mineral) and inorganic fertilizer. The experimental design was set up in a Randomized Complete Block Design (RCBD) with 4 treatments (control- without compost and inorganic fertilizers, inorganic fertilizer-2:3:4 (30) - 5g Zn% and LAN (28), WWC application at different application rates were (3485g/plot) (100%) and (13939g/plot) (400%)) replicated four times.

Soil analysis showed that the experimental plot is dominated by sandy soil structure. Results of mineral analysis after application of treatments showed a significant ($p>0.05$) drop in soil pH over time in the untreated control and application of 400% WWC significantly ($p<0.05$) raised soil pH compared with the control. The application of mineral fertilizer showed significant ($p<0.05$) increase in soil P compared with the other treatments. However, WWC picked up significant ($p<0.05$) speed above inorganic fertilizer, thus making P available to the soil than NPK mineral fertilizer. A significant ($p<0.05$) drop in soil K content by 21% over time on amended soil with inorganic fertilizer treatment was observed. However, the application of WWC at 300 and 400% significantly ($p<0.05$) raised the soil K by 54.93 and 73.06% respectively.

There were no significant differences in soil Ca over time, but high soil Ca concentrations from WWC (100%) were recorded compared to inorganic treatment that showed the lowest soil Ca concentration. There was a slight drop in soil Na over time in control and soil amended with inorganic fertilizer. The effects of the treatment on Mg values were not so prominent, suggesting that concentrations of nutrients are less essential characteristics of the soil or small portion of nutrients were readily available on the soil.

Leaf increase (Swiss chard) was observed from all treatments with plants derived from WWC showing high significant ($p<0.05$) number of leaf compared to plants subjected to inorganic fertilizer and control. No significant ($p<0.05$) increase in leaf length, breadth and area from week four to week eight. In respect to leaf chlorophyll content, no significant ($p<0.05$) difference due to treatment effects. The results of fresh leaves (weight) revealed that fresh weight was significantly ($p<0.05$) influenced by different treatments applied. However, no significant difference on all treatments for dry leaves (weight) of the Swiss chard. Mineral fertilizer showed significant ($p<0.05$) 12.3% and 35.8% yield increase for N and Mg respectively compared with other treatments. In addition, Swiss chard accumulated significantly ($p<0.05$) high P and K in its leaves compared with the other treatments while Ca and Na were significantly ($p<0.05$) higher in the control treatment.

Inorganic fertilizer and 400% WWC significant ($p<0.05$) perform better at eight weeks (cabbage) than the other treatment levels and harvest time respectively. Similarly, inorganic fertilizer consistently recorded significant ($p<0.05$) higher chlorophyll content than the other treatments. On cabbage yield, no significant difference between treatments, except for control which showed low mean value. The fresh cabbage leaves (weight) were significantly different ($p<0.005$) between treatments. However, on dry leaves (weight) there is no significant ($p<0.05$) difference between treatment.

Inorganic fertilizer showed significant ($p<0.005$) N accumulation in the tissue of cabbage compared with the treatments followed closely by WWC with a significant ($p<0.005$) yield drop of 15.5% (WWC 100%) and 10.6% (WWC 400%) respectively. Similarly, inorganic fertilizer significantly ($p<0.005$) improved the Na content in cabbage compared with the other treatments. The 400% WWC favored significant ($p<0.005$) accumulation of P and K in the tissue of the species while WWC 100% also significantly ($p<0.005$) outperformed inorganic fertilizer for K by 20.1%. The control treatment showed significant ($p<0.005$) Ca and Mg yield increase compared with the other treatments. Overall, this study demonstrated a significant potential for the introduction of WWC as organic fertilizer in the cultivation of cabbage and Swiss chard in the area.

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RESEARCH OUTPUTS

The following research outputs represent contributions by the candidate to scientific knowledge and development during his master's candidacy:

 Publication

Ndololwana , N.G., Lewu, F.B. & Mulidzi, R. Influence of winery waste compost and NPK mineral fertilizer on sandy soil chemical properties and yield of *Brassica oleracea* var. *capitata* L. Submitted to *Journal of Applied Botany and Food Quality (2016).*

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GLOSSARY

Abbreviation	Description
ADP	Adenosine diphosphate
ATP	Adenosine triphosphate
Ca	Calcium
CEC	cation exchange capacity
DAFF	Department of Agriculture, Forestry and Fisheries
DNA	Deoxyribonucleic acid
g	Gram
H_2PO4^-	Dihydrogen phosphate
$HPO4^-$	Hydrogen phosphate compound
ICP-OES	Inductively Coupled Plasma/Optical Emission Spectrometry
K	Potassium
KCl	Potassium chloride
LSD	Least significant differences
Mg	Magnesium
mg/kg	Milligrams per kilogram
N	Nitrogen
Na	Sodium
$NH4^+$	Ammonium
$NO3^-$	Nitrate
P	Phosphorus
pH	power of Hydrogen
RNA	Ribonucleic acid
S.A	South Africa
WWC	Winery waste compost

Clarification of Terms

Imifino: traditional meal where leaves of Swiss chard or cabbage are mixed with maize meal in Xhosa tradition

Antihistamine: a compound that inhibits the physiological effects of histamine, used especially in the treatment of allergies.

Eutrophication: a process where water bodies receive excess nutrients that stimulate excessive plant growth.

Evapotranspiration: loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

CHAPTER ONE
1. INTRODUCTION

The ability to reuse winery solid waste would be beneficial to the wine industry, as it could potentially be a cost-effective method of solid waste management, whilst at the same time providing a valuable organic resource. The wine industry is an important sector in the economy of South Africa (S.A), (Van Schoor, 2001). The composting of solid winery waste is an alternative to the traditional disposal of residues and also involves a commitment to reducing the production of waste products (Bertran *et al.,* 2004).

The process of winemaking results in massive generation of solid wastes such as grape skins, seeds and filter cakes. Small wineries attempted to dispose their wastes through waste processing companies but the costs are very high because most waste processing companies are not willing to collect small amounts of waste (Bustamante *et al.,* 2011; Nóvoa_Muńoz *et al.,* 2008). Some wineries use winery solid wastes for composting purposes but without the knowledge of its potential impact on soil and the environment (Walsdorff *et al.,* 2004) they have insufficient knowledge on the beneficial properties of winery waste (Embrandiri *et al.,* 2013).

Wine producers in S.A dump their winery solid wastes at landfills. However, this method has serious legislative restrictions hence such waste disposal is quite expensive due to scarcity of land. Dumping diatomaceous earth (DE) and perlite without proper treatment may result in soil and water pollution, thus affecting the performance of natural vegetation and human health (Van Schoor, 2001).

The disposal of winery solid waste without proper treatment may lead to soil, air and water pollution (Van Schoor, 2001). Composting of winery waste for use in crop production may be an alternative waste disposal technique to landfill and incineration (Yanai *et al.,* 2004; Consortium, 2010). A more attention has to be given to possible ways that will improve soil fertility and health without causing detrimental effects on soil and water. Composts from waste such as sewage sludge have been reported to improve soil fertility and soil physical conditions (Van Schoor, 2001).

Composting has been shown to be an efficient treatment to recycle wastes, thus providing potentially valuable resources for use in agriculture, both for supplying nutrients and for replenishing soil organic matter (Walsdorff *et al.,* 2004; Bustamante *et al.,* 2008a). Some reports showed that composting of solid wastes is a better management option because of their high nutrient content (Embrandiri *et al.,* 2013). There is an increasing demand of organic fertilizers, such as compost, from agricultural sector (Trillas *et al*., 2002; Borrero *et al*., 2004).

Agriculture remains the key sector for the economic development of S.A. Rising food prices have become a global phenomenon and S.A is not immune to it either. The constant increases are mainly the result of the rising input costs, the exchange rate, competing demands and climate change. Agricultural sector is now recognized as the engine room of growth that will drive poverty reduction in S.A and improve the livelihood of its population (Venter, 2011).

The demand for organically produced vegetables due to its health and nutritional benefits is ever increasing (Arzefoni *et al*., 2013). Low soil fertility is one of the main factors responsible for low productivity of vegetable crops. Soil fertility can be enhanced by use of organic or in combination with inorganic fertilizer to improve yield (Bationo *et al*., 2010; Hasan and Solaiman, 2012).

However, the use of any type of fertilizer depends on several factors such as soil type, nature of crop and socio-economic conditions of the area. High quality soil is the backbone of a sustainable crop. Well-managed soil supports healthy, vigorous root growth, which improves plant resistance to soil diseases. Soil improvement requires a long-term management plan to increase soil organic matter, feed beneficial soil microbes and ensure nutrient supply to plants.

Organic fertilizers can therefore be used to reduce the amount of toxic compounds (such as nitrates) produced by conventional fertilizers in vegetables like lettuce. Organic system can improve the quality of leafy vegetables as well as human health (Masarirambi *et al.,* 2010). Sandy soils generally have low holding capacity, therefore hold little water (Ibhrahim *et al.,* 2013).

The knowledge and research on the use of winery waste compost for growing vegetables in sandy soils is limited. The objective of this study is to evaluate the use of solid winery waste compost to establish cabbage (*Brassica oleracea* var. capitata) and Swiss chard (*Beta vulgaris subsp.cicla*) on sandy soil at Bien Donné experimental farm near Paarl in the Western Cape region.

1.1 HYPOTHESES

i. Application of winery solid wastes composts will have no effect on the chemical characteristics of sandy soil.

ii. The growth and yield response of Swiss chard and cabbage following application of composted winery solid wastes will be comparable to inorganic fertilizer application.

iii. The optimum application rate of the different winery solid wastes composts can be determined for Swiss chard and cabbage.

1.2 OBJECTIVES

i. To determine the effect of winery solid waste compost on crop growth and yield for Swiss chard and cabbage as test crops.

CHAPTER TWO
2. LITERATURE REVIEW

2.1 LEAFY VEGETABLES (*Brassica oleracea* var. capitata L. and *Beta vulgaris* subsp. *cycla*)

Vegetables form a vital part of human diet because they are the source of many vitamins, minerals, proteins (Masarirambi *et al*., 2012). Leafy green vegetables are well known for their characteristics color, flavor and healing value (Mitic *et al*., 2013). The introduction of vegetables to the farming system would not only generate the much needed income for families but, would also improve people's diets (Rono *et al*., 1997).

A plant-based diet-focusing mainly on vegetables has become one of the most important guidelines for lowering the risk of human diseases (Masarirambi *et al*., 2010; Mitic *et al*., 2013). Vegetable plants and humans have unique relationship since time immemorial and they play a vital role in the human life. Therefore, there is a need to improve the nutritive value of the final products (high quality) of vegetables for human consumption (Ramteke and Shirgave, 2012).

Leafy vegetables have a high nutritional requirement (Masarirambi *et al*., 2012), which is influenced by environmental factors such as light, temperature, mineral nutrients and moisture availability (Gutiérrez-Rodríguez *et al.,* 2012). Olaniyi and Ojetayo, (2011) reported that green outer leaves of cabbage are richer in vitamin A, calcium and iron than the white inner leaves. Efficient growth and high yield of crops are important factors when considering the use of compost as nutrient source in vegetable production (Okorogbona *et al*., 2011).

2.2 HISTORY OF SWISS CHARD (*Beta vulgaris* subsp.*cycla*)

Swiss chard also referred to as 'Spinach' by most people in S.A (DAFF, 2010), is a biennial; but it is grown as annual and is a very close relative to beetroot (Citak and Sonmez, 2009). Spinach is a popular substitute for true Swiss chard (*Beta vulgaris* subsp*. cycla*) and belongs to the Chenopodiaceae plant family, (Citak and Sonmez (2009), which includes the root vegetable (*Beta vulgaris* L.Crassa group) (Maynard and Hochmuth, 1997). Swiss chard is known as a heavy feeder and requires high levels of nitrogen for healthy growth and development (Smatanova *et al*., 2004). In S.A the crop is mainly grown in KwaZulu-Natal and other provinces (DAFF, 2010).

Dark green, leafy vegetables are typically packed with nutrients and Swiss chard is no exception. Swiss chard is often considered the most nutritious vegetable due to the variety and amounts of vitamins, minerals and health-promoting phytonutrients it contains. Raw Swiss chard is nutritious, although it contains a high concentration of oxalic acid, which can cause digestive and absorptive issues (Leskovar and Piccinni, 2005). Boiling Swiss chard reduces the oxalic acid content, but it also leads to loss of nutrients and texture. Women with calcium or vitamin D deficiency (osteoporosis) should be aware of this connection and not rely on Swiss chard as a significant source of calcium (Dubois*,* 2003).

2.2.1 Interesting facts about Swiss chard

Swiss chard is quick to cook, using just a small amount of water to boil and can be eaten raw. It can be used in lots of recipes including soups, quiches, curries, pates and soufflés. Swiss chard contains lots of good vitamins including beta-carotene, and vitamins A, B and C and minerals such as iron and folic acid (DAFF, 2010). It is cooked briefly to minimize losing the important vitamins and minerals (Dubois*,* 2003). Swiss chard is a highly valuable leafy vegetable with good cooking adaptability (Nishihara *et al*., 2001).

2.2.2 Nutritional profile for Swiss chard

Swiss chard is an excellent source of vitamins K and A, folic acid, dietary fiber and protein, very good source of vitamins C and E, most B vitamins and numerous minerals, especially calcium, potassium, phosphorus and manganese, as well as respectable amounts of niacin, and folic acid (Smatanova *et al*., 2004; Leskovar and Piccinni, 2005; Citak and Sonmez, 2009). Swiss chard is very low in saturated fat and cholesterol, but it's naturally quite high in sodium (Mitic *et al*., 2013).

The species is also concentrated in health-promoting phytonutrients such as carotenoids and flavonoids, which provide powerful antioxidant protection (Bímovà and Pokluda, 2009; Fairman, 2011). Many of these vitamins and nutrients help fight various types of cancer and promote good cardiovascular health (Masarirambi *et al*., 2012). Swiss chard, like some other dark leafy green vegetables, also contains protectors of lipid membranes against oxidative damage, which research has indicated may help in fighting blindness (Dubois*,* 2003).

UBISI MAIL, (2009) reported that although Swiss chard is low in calories and is good for healthy diet, many doctors advises that it should not be eaten more than twice a week. They also recommend that pregnant women eat Swiss chard during the first three months of pregnancy, because Swiss chard contain folic acid which is good for the development of the baby-but stick to eating it only two times per week (Sea Grant / Great Lakes Restoration, 2011). Swiss chard can reduce the risk of cancer and can even protect eyes and heart from growing weak (Fairman, 2011). Swiss chard is quite nutritious and the significance of vegetables in a human diet is shown in numerous studies.

2.2.3 Factors affecting yield and quality of Swiss chard

2.2.3.1 Growing conditions

Swiss chard grows better in cooler weather and requires optimum temperatures between 7 and 24°C to germinate (DAFF, 2010). Young plants can withstand temperatures as low as 9ºC and during hot weather, leaves remain small and are of inferior quality (Citak and Sonmez, 2009).

2.2.3.2 Soil type

Swiss chard likes sandy soil because it has a shallow root system that cannot dig too deeply into dense soils such as clay (Hainer, 2006) and for this reason require a large percentage of magnesium to reduce the size of soil pores and reduce the water infiltration (Farmer's weekly, 2007). Sandy soils need some compost to increase their ability to hold water and nutrients (Hainer, 2006).

2.2.3.3 Soil pH

Soil pH indicates the availability of nutrients and does not identify which elements are deficient or in excess. Soil pH does have an impact on production and can result in many problems when it is too high or too low. Mitic *et al*. (2013), indicated that Swiss chard is not the easiest of vegetables to grow and is one of the few that prefer a neutral to high pH. Swiss chard grows best in soil that learns towards alkaline as it is sensitive to acid soils, ideally with a pH of 6.4 to 6.8 (DAFF, 2010). Too much acid in the soil leads to yellow or brown leaves, poor root structure and dying plants (Hainer, 2006).

2.2.4 Irrigation

Irrigation helps maintain uniform growth and is critical for high quality and crop yield (Mitic *et al*., 2013). Leskovar and Piccinni (2005), reported that Swiss chard stem development and height increased when irrigated more frequently which leads to earlier growth and greater harvest leaf area, leaf fresh and dry weight. Koike *et al*. (2011), reported that Swiss chard fields are sprinkler irrigated to ensure the germination of the crop, whereas (DAFF, 2010) disapprove the use of sprinkler irrigation due to increased incidence of foliar diseases experienced with this method. The advice will then be to irrigate during the day if using sprinkler irrigation so that all the water evaporate off the plant foliage before dark and that will reduce disease incidence.

2.2.5 Fertilization

Fertilizer programmes must be based on soil analyses for the specific land. Smatanova *et al*. (2004), reported that vegetables have very high demands for available nutrients in the soil, and need a uniform nutrients supply (Farmer's weekly, 2014). Khan *et al.* (2007), reported that chemical fertilizer promotes the accumulation of nitrate in Swiss chard. However, Hosseny and Ahmed (2009), reported that slow release of nitrogen in compost can modify the nitrate content in Swiss chard. Borowski and Michalek (2009), reported that one hectare of Swiss chard cultivation needs the application of about 80-90 kg N, 40-60 kg P_2O_5 and 80-120 K_2O. Swiss chard is a hungry crop and needs to be fed with nitrogen to ensure they stay healthy and vigorous. When nitrogen is low, especially when that is combined with a lack of potassium, the plant is more vulnerable to leaf diseases (Farmer's weekly, 2014).

2.2.6 Weed control

Hand-weeding is an expensive component of crop production. A more economical alternative is to hoe the field when weeds are small and have not flowered yet. Herbicides are also available to use in a Swiss chard crop (Farmer's weekly, 2014). Good weed control requires integration of cultural and chemical methods. Swiss chard should be planted to land free of perennial weeds, where the annual weed seed population has been reduced by cultural practices such as crop rotation, stale seedbed or hoeing (DAFF, 2010).

2.2.7 Pest and disease control

Swiss chard leaf miner and aphids are the most frequent pests of Swiss chard. Control can be done by destroying infected crop residue and weeds. Also use registered pesticides. Apply management strategies for diseases and pests, including crop rotation and spraying with registered insecticide and fungicide (Koike *et al*., 2011). Diseases include downy mildew, wilt and yellow rot, Swiss chard blight or yellows and damping off. These can be controlled by treating the seeds with a registered chemical immediately before planting or by planting resistant cultivars (DAFF, 2010).

2.3 HISTORY OF CABBAGE *(Brassica oleracea* var. *capitata* L.)

Cabbage is one of the oldest vegetables. Cabbage (*Brassica oleracea* var *capitata* L.), is a plant of the family *Brassica-leae* and related to turnips, cauliflower and brussels sprouts (Olaniyi and Ojetayo, 2011). Cabbage is herbaceous biennial with leaves that form a compact head (Hasan and Solaiman, 2012). It was originally found growing wild on the seashore of southern Europe, England and Denmark. In S.A, many leafy vegetables used to be obtained by collection from the wild and not by means of cultivation until recently when research emphases have been laid on domestication (Okorogbona *et al.*, 2011).

2.3.1 Factors affecting yield and quality of cabbage

2.3.1.1 Soil types

Cabbages grow well on a wide range of soils from light sand to heavier clays. Soils with high organic matter content give the best yields. The soil pH should be in the range of 6.0–6.8 for ideal growth. Cabbages are less demanding than cauliflowers, and good crops can be produced on most soils. Good drainage is important, and soils that become waterlogged after heavy rain or irrigation are unsuitable (Napier, 2006).

2.3.1.2 Irrigation

Cabbages need regular irrigation to ensure rapid growth and evenness of maturity. They can be irrigated by moveable spray lines, travelling irrigators or solid set, or, if the soil is suitable and water available, flood irrigation (Olaniyi and Ojetayo, 2011). Cabbages grown in beds will require more irrigation than those grown on the flat. Soil type and weather will also influence the frequency of irrigation. The use of tensio meters or other measuring equipment will improve yields and reduce water costs (DAFF, 2010).

2.3.1.3 Fertilization

Suitable fertilizer programmes based on reliable soil analysis should be developed for each field. Cabbage is a heavy user of nitrogen, phosphorus and potassium (Mochiah *et al.,* 2011). Cultivation of cabbage needs proper supply of plant nutrients and water (Mckowen *et al.,* 2009; Hasan and Sulaiman, 2012), in the absence of fertilizer the soil is unable to maintain the expected productivity levels, but they can be maintained by the use of combinations of reduced levels of organic manures and inorganic fertilizer (Rono *et al.*, 1997). The main factor in soil fertility is the level of soil organic matter (Daizell *et al*., 1987), which improves soil structure leading to better moisture retention, increased availability of P in the soil, reduced leaching and increased soil microbes (Rono *et al*., 1997).

Hasan and Solaiman (2012), reported that the level of nitrogen fertility has more influence on the growth and yield of cabbage than any other single plant, it is most often deficient in sandy soils, however studies conducted by (Browder, 1990; Mochiah *et al.,* 2011) suggested that excessive use of these agrochemicals may increase pest problems. Phosphorus and potassium are more important during the expansion of the outer leaves (Rono *et al*., 1997).
Growth and yield of cabbage vegetable is remarkably influenced by organic and inorganic nutrients (Hasan *et al.,* 2012). It is an established fact that the use of inorganic fertilizer for

the crops is not so good for health (Abedi *et al*., 2010; Islam *et al*., 2011; Arzefoni *et al.,* 2013) because of residual effect but in the case of organic fertilizer such problem does not arise and on the other hand it increases the productivity of soil as well as crop quality and yield (Hasan *et al*., 2012). According to the experiment conducted by Hasan and Solaiman (2012), it showed that the response of cabbage is high to nitrogen application and moderate to phosphorus application.

2.3.2 Nutritional profile for cabbage

People should consume several 100g of plant-based diet a day since it is a good source of nutrients and dietary fibre. Cabbage flavor can be sweet, bland, or strong, depending on the variety (Leskovar and Piccinni, 2005). Strong flavors derive from sulfur-containing compounds. Cabbage is an excellent source of vitamin C and a good source of vitamin A. It contains quercetin, an antioxidant that is a natural antihistamine that can benefit allergy sufferers. A chemical (isothiocyanates) found in cabbages may lower the risk of lung cancer in smokers by as much as 38%. It has been shown to reduce the risk of breast cancer (Nolte, 2013).

2.3.3 Cabbage pests and diseases

The cabbage plants attract a number of insect pests at different stages of the plant growth due to their nutritious and flourishing nature (Mochiah *et al.,* 2011). Cabbage is attacked by several aphids but the grey cabbage aphid (Brevico-rye brassicae) and the green peach aphid (*Myzuspersicae*) are the most common. Damage is caused when they suck sap from the plant and contaminate the eatable product. Feeding of the cabbage aphid causes a chlorosis and malformation of the leaf. Various diseases attack cabbage and this can lead to serious economic loss. Infected seedlings wilt, turn purple and die, and often have no lateral roots (DAFF, 2010).

2.3.4 Weed control

Weeds need to be effectively controlled because they are competing with the crop for nutrients, moisture and sunlight. Some weeds show chemical substances which may stop the growth of the crop (Farmer’s weekly, 2014). It is very important that weeds be controlled in the early stages of the crop development, because early competition can adversely affect plant growth and result in the lowering of crop yields. Weed control can be achieved mechanically, by hand, chemically, or by a combination of these methods (DAFF, 2010).

2.4 PLANT NUTRIENTS

Nutrient balance is the key component to increase crop yield (Datt *et al.,* 2013). There are not always enough of these nutrients (nitrogen, phosphorus and potassium) in the soil for a plant to grow healthy. This is why many farmers and gardeners use fertilizers to augment soil nutrients. These major nutrients: N, P, and K are usually lacking from the soil because plants use large amounts for their growth and survival (Singh *et al.,* 2011).

2.4.1 Nitrogen

Plants need nitrogen to build proteins and to produce the green pigment chlorophyll, which is essential in photosynthesis process, in which plants use water, carbon dioxide and sunlight to produce their own food (Mochiah *et al.,* 2011). Plants are genetically programmed to absorb as much nitrogen as possible, so it gets pulled out of the soil fairly quickly (Mckowen *et al*., 2009).

Plants can take up nitrogen (N) either as inorganic ions ($NH4^+$ or $NO3^-$), or as organic N (Ibrahim *et al*., 2013). Nitrogen is one of essential elements for growth and development of plants (Zebarth *et al.,* 1991). Plants absorb nitrogen from soil in the form of nitrates, which are then converted into proteins and other nitrogen-containing substrates and metabolites. Nitrate content in plant represents a dynamic balance between rate of absorption, assimilation and translocation (Hosseny *et al.,* 2009).

Nitrogen is needed by all plants, usually in large quantities. Nitrogen is so important to plant growth, and thus to the world's food and production. Nitrogen from compost must first be released from its organic substrates, and this process may take several days to several months. Depending on the type of organic material and the environmental conditions, such as temperature and moisture, only 10–50 % of the N from an organic source would be converted to $NH4^+$in a 6 months period (Hue *et a*l., 2000).

When plants do not have enough N, they are stunted, with small leaves that may be pale yellow-green sometimes completely yellow or red-tinted. Nitrogen is also a component of chlorophyll; less N results in less chlorophyll, and thus less green color, less photosynthesis, and less crop growth (Rosen and Bierman, 2005). Nitrogen deficiency begins in older leaves and then progress upward toward the growing point. In soils, N must be present as either $NH4^+$ or $NO3^-$before plants can absorb and use it (Hue *et al*., 2000).

In a study using fresh poultry manure and slurry, Stockdale and Rees, (1995) found that N release was quick compared with farm yard manure, pig manure and sewage sludge where initial N release was slower but sustained over a longer time period. Cooperband *et al.* (2002), observed that nitrate released from composted poultry manure (composted for 1, 4 and 15 months) was 3-4 times lower than from raw poultry manure, and that available soil nitrate-N from composts was no greater than from an unfertilized control.

2.4.2 Phosphorus

Phosphorus (P) is needed by plants in much smaller quantities than nitrogen, but like N deficiency, P deficiency in soils commonly limits crop production (Deenik *et al.,* 2006). Phosphorus is a structural component of DNA and RNA, genetic materials essential for growth and reproduction. Phosphorus-containing compounds, mainly adenosine diphosphate (ADP) and adenosine triphosphate (ATP), are the internal energy source for plant and animal metabolic processes. P-deficient plants, therefore, are stunted, with limited root systems and thin stems. Phosphorus-deficient seedlings look stunted, and older leaves may turn purple because of an accumulation of purple pigments (Hue *et al*., 2000).

With continued application of composts and manures, soil P levels will increase (Sharpley and Rekolainen, 1997). In soils already high in P, addition of composts and manures carries with it a risk of P runoff. Plants extract P from the soil solution in the form of orthophosphate ion (H_2PO4^- or $HPO4^-$). There is strong competition between plants and soil minerals for these forms of P when they are free in the soil solution, and the soil usually wins (Warman and Cooper, 2000).

The amount of P required as fertilizer depend on how much P the soil has in the first place. That is why soil test need to be done before trying to amend soils or fertilize crops. Adding phosphorus to the soil year after year, might build up soil P to the point that it becomes detrimental to plants because of excess. The reason for this is that unlike N, P does not move easily with water, and loss from leaching is minimal (Hue, 1990)**.**

2.4.3 Potassium

Movement of potassium (K) depends on soil texture. In sandy soils, potassium is quite mobile and can actually leach out of the root zone whilst in clay the movement decreases. In compost, K remains in water-soluble forms and thus does not need to be mineralized before becoming plant available. However, for the same reason it is at risk of leaching during the composting process and thus compost is often a poor source of K (Barker, 1997). Composting of organic wastes does not appear to affect K availability but application may affect both soil K (Wen *et al.,* 1997; Warman and Cooper 2000; Baziramakenga *et al.*, 2001) and plant K uptake (Chen *et al.*, 1996). Compost made from grass and straw has been shown to contain approximately twice the K content of chicken manure (Eklind *et al*., 1998).

Potassium also plays a role in protein production and photosynthesis, as well as helping control the plant’s metabolism and building its resistance to disease. Potassium, like N, is needed in large quantities by most crops. It is required in plants for maintaining the water content of cells, it helps keep plant tissues turgid. Potassium plays an important role in plant water relations by regulating the osmotic potential of cells and the closing and opening of leaf stomata, the openings in the leaf surface that allow moisture to escape, cooling the plant (Baziramakenga *et al.*, 2001). It is involved in water uptake from the soil, water retention in the plant tissues, and transport of water in the xylem and photosynthates in the phloem. Potassium affects cell extension with adequate K, cell walls are thicker, thereby improving plant resistance to lodging, pests, and diseases (Eklind *et al*., 1998).

Fruits and vegetables grown with adequate K seem to have longer post-harvest storage life. Potassium-deficient plants have low resistance to disease, and their seeds and fruits are small and shriveled (Weibel *et al.,* 2000). In tomato, K deficiency results in smaller fruits with incomplete flesh development; in corn, maturity is delayed and ears are smaller. The most readily observed K deficiency symptom is scorching of leaf tips and edges (Wen *et al.,* 1997). Potassium-deficiency shows small white or yellowish spots around the outer edges of the leaves. As the deficiency intensifies, the leaf edges turn yellow, then brown, and finally the leaf dies. K deficiency occurs more often in sandy than in clayey soils (Hue *et a*l., 2000). One way to reduce K leaching is to incorporate organic soil amendments such as compost or manure. Organic materials usually have a large cation exchange capacity, enabling them to retain K ions effectively (Hue *et a*l., 2000).

2.5 INORGANIC FERTILIZERS VS COMPOST

2.5.1 Background

Inorganic fertilizer is made by converting nitrogen in the air into liquid ammonia. Production of synthetic nitrogen was inexpensive and profitable in the early 1900s (Warman and Cooper, 2000). The product was promoted worldwide as a solution to hunger, but is now held responsible for global toxic nitrogen overload. According to Singh *et al.* (2011), chemical fertilizers boost up crop production initially and gradually causes decrease in fertilizer use efficiency resulting in depletion of soil nutrients and disruption of eco-balance of soil-plant system. Compost is decomposed organic matter that helps build healthy soil by stimulating and feeding many beneficial soil micro-organisms. Along with adding nutrients, compost helps soil hold water (and nutrients) and air. Compost works on any soil; it helps sandy soil to hold nutrients and water, and it loosens clay soils (Sea Grant / Great Lakes Restoration, 2011).

2.5.2 Benefits of compost to the soil

Composted organic material is applied to agricultural fields as an amendment to provide nutrients and also to enhance the organic matter content and improve the physical and chemical properties of cultivated soils. Compost is a good source of plant nutrients, and also of 'food' for endemic soil microbes, encouraging them to multiply and do their work in the soil (Masarirambi *et al*., 2010). Land application of composted material as a fertilizer source not only provides essential nutrients to plants, it also improves soil quality and effectively disposes of wastes (Golabi *et al.*, 2010).

Organic fertilizer is more apt to be a focus, as it may contribute to the reduction of the use of the chemical fertilizer, which has been causing environmental problems such as eutrophication in water system or land degradation (Mihara *et al.,* 2007; Odhiambo and Magandini, 2008). Composts have the potential to provide biological control of various disease pathogens, particularly the soil-borne pathogens through microbial actions (Nahar *et al*., 2012). Compost as the organic waste can be a valuable and inexpensive fertilizer and source of plant nutrients. Besides the positive effect of organic fertilizer on soil structure that lead to better root development which result in more nutrient uptake (Hasan and Solaiman, 2012).

Compost not only slowly releases nutrients but also prevents the losses of chemical fertilizers through denitrification, volatilization and waste may improve the efficiency of chemical fertilizers and thus reduce their use in order to improve crop productivity as well as sustain soil health and fertility (Abedi *et al.*, 2010).

Organic manures, apart from improving physical and biological properties of soil, help in improving the efficiency of chemical fertilizers (Abd-Alla *et al.*, 1999). The continued use of chemical fertilizers causes health and environmental hazards such as ground and surface water pollution by nitrate leaching (Abedi *et al.*, 2010; Masarirambi *et al*., 2012; Ibrahim *et al.*, 2013). Organic manures such as farmyard and poultry manure are known to improve the physical, chemical and biological conditions of soil and ensure sustainable soil health (Logan *et al.*, 1997).

Hakkinen *et al.* (2000), compared the phenolic content in three cultivars of strawberries grown organically and conventionally. They reported that only one cultivar grown under organic conditions showed higher levels of phenolics than its inorganically grown counterparts. Asami *et al.* (2003), reported significantly higher total phenolics in marion berries grown with organic fertilizer as compared with inorganic fertilizer. Weibel *et al.* 2000, indicated that the phenol (mainly flavonols) content of organically grown apple cultivars was

19% higher than in apples grown using inorganic fertilizers. These results suggest that the usage of organic fertilizers can enhance the production of plant secondary metabolites.

Organic matter persistence in soil will vary with temperature drainage, rainfall and other environmental factors. Organic matter in soil improves moisture and nutrient retention and soil physical properties (Masarirambi *et al.,* 2012). Inorganic fertilizer is said to reduce the antioxidant levels, while organic fertilizer has been proven to enhance antioxidant content in plants (Dumas *et al.,* 2003). Previous studies showed that the combination of compost with chemical fertilizer further enhanced the biomass and grain yield of crops. Integrated use of organic wastes and chemical fertilizers is beneficial in improving crop yield, soil pH, organic carbon and available N, P and K in soil (Abedi *et al.,* 2010).

According to Bationo *et al*. (2010), yields can be increased three to five times with the improvement of soil fertility using organic and inorganic fertilizers. Combinations of these materials also improve an array of other soil properties such as organic carbon content, cation exchange capacity (CEC) and pH. Bationo *et al*. (2010), study concluded by stating that the main constraint to combining inorganic-organic materials is the high costs of inorganic fertilizers and the low availability of organic fertilizers at the farm level.

Civeira, (2010) and Masarirambi *et al.* 2012, reported that the use of composted organic wastes produces changes in soil physical, chemical and biological properties and can enhance plant growth after its application. However, the influence of Carbon rich materials, like municipal organic wastes compost, on soil physical, chemical and biological properties depends upon several factors: amount and components of added organic materials, soil type and weather conditions (Civeira, 2010). In a study conducted by Hue (1992), green manures and composted organic material increase soil organic matter and provide plant nutrients, alleviate aluminum toxicity, and render phosphorus more available to crops. This increased availability of phosphorus is believed to be the result of the reaction of organic matter-derived molecules with soil minerals (Hue, 1992).

Organic matter additions are the only means of making some soils economically productive. Well-decomposed organic matter has a very high cation-exchange capacity that adds to the buffer capacity of the soil. An adequate supply of soil organic matter makes it safe to apply rather large applications of fertilizer at planting time and thus avoid the need for a second application (Cook and Ellis, 1987). The process above can save the farmer some input cost to crop production in the form of man power.

Organic compost has been shown to increase soil organic matter, enhance root development, improve germination rates and increase water-holding capacity of soils. Application of organic material promotes biological activity, enhances nutrient exchange capacity, improves water balance, increases organic matter content and improves the structure of the soil (Zibilske, 1987; Muse, 1993). Compost can also be applied as a mulch to promote percolation, reduce weeds and conserve water by reducing evapotranspiration from the soil (Muse, 1993).

2.6 USE OF COMPOST ON SANDY SOIL

Low soil fertility is one of the main factors responsible for low productivity of vegetable crops. Sandy soils are generally regarded as very fragile with respect to agricultural production due to their very low nutrients and organic matter contents (Boul *et al*., 2003; Wambeke, 1992). Agricultural productivity on such soils is hence considerably low (Ibrahim and Fadni, 2013).

Sandy soil has the opposite problems to that of the clayey soil. Water runs right through sandy soil and none is caught between the soil particles. This means that plants have little water or food, because the nutrients are washed out of the soil profile. Sandy soils have high proportion of sand and little clay. These soils drain quickly after rain or irrigation. However, sandy soil offers benefits including; easy to cultivate and work, excellent drainage, good air circulation and less pest incidence (Ibrahim and Fadni, 2013).

A great deal of research indicated that sandy soils are often very acidic and to improve these soils, addition of compost and plenty of other organic materials can enhance soil characteristics favorable for root growth, increase microbial activity, add nutrients and enhance physical properties (Muse, 1993; Busari *et al., 2008*). Compost can greatly enhance the physical structure of soil (Muse, 1993). The soil-binding properties of compost are due to its humus content. Humus is a stable residue resulting from a high degree of organic matter decomposition. The constituents of the humus act as soil 'glue,' holding soil particles together, making them more resistant to erosion and improving the soil's ability to hold moisture (Darlington, 2009).

Soils with low cation exchange capacity, especially sandy soils benefit from addition of soil organic matter which creates better conditions for nutrient retention and uptake by plants. Compost contains humus, that loosely binds nutrients and builds up the capacity of the soil to store and release nutrients for plant growth (Masarirambi *et al*., 2012). Too much nitrogen on plants can be detrimental for plant (Browder, 1990).

However, the release of available nitrogen from organic compounds during manure decomposition is very gradual. This slow release of nitrogen is manure's most important asset. It extends nitrogen availability and reduces leaching of particular importance in sandy soils (Mochiah *et al.,* 2011).

Among the practices recommended for improving the soil quality and soil fertility, the application of composted organic wastes supply plant nutrients, organic compost has been shown to increase the level of soil organic matter, enhance root development, improve the germination rate of seeds, and increases the water-holding capacity of soil. Applied organic materials promote biological activities in the soil, as well as a favorable nutrient exchange capacity, water balance, organic matter content and soil structure (Masarirambi *et al*., 2012).

Compost can increase the water holding capacity of sandy textured soils, improve structure and water movement through heavier textured soils that are high in silt and clay content. By increasing the organic content of the soil, biological activity can be enhanced. Water and nutrient holding capacity can be improved in some soils. Some compost has the ability to suppress fungal diseases (Darlington, 2009). Compost supply many nutrients for crop production, including micronutrients and are valuable source of organic matter (Rosen and Bierman, 2005).

2.7 SOIL pH

The pH of the soil is important for plants because if the pH is too high or too low, the nutrients the plants require cannot dissolve into the soil solution and are therefore unavailable to the plants. A pH of 7 is neutral, a pH below 7 is acid and a pH above 7 is alkaline. Almost all vegetables prefer soil on the acid side, between 6.5 and 7 (Maynard and Hochmuth, 1997). This is also the optimal range for bacterial growth, which promotes decomposition.

The addition of compost to soil may modify the pH, depending on the pH of compost and soil. Compost addition may raise or lower the pH (Boul *et al*., 2003). Therefore, the addition of neutral or slightly alkaline compost to acidic soil will increase soil pH if added in appropriate quantities. Compost has been found to affect soil pH when applied. The incorporation of compost also has the ability to buffer or stabilize soil pH, whereby more effectively resist pH change (Wambeke, 1992).

Nitrogen is most available at a neutral pH because the microbes that convert nitrogen into the usable forms of ammonia and nitrate operate best at near-neutral pH levels. Compost consists of large, complex, and diverse compounds that provide both negatively-charged attachment points and numerous hydrogen atoms (Hue and Silva, 2000). Which of these comes into play depends on the pH of the soil in which the compost is placed. Acidic soil suffers from an overabundance of positively-charged hydrogen ions. When compost is added, its many negatively charged attachment sites attract and bind hydrogen. When enough hydrogen ions are taken out of solution, the pH level of the soil rises (Ibrahim *et a*l., 2013).

In alkaline soil, compost's complex, hydrogen-rich molecules provide a source for hydrogen ions. Many get stripped away, leaving their electrons behind, which means that they have become positively charged ions. When enough ions are released into the soil solution, the pH falls. The negatively charged sites on the compost molecules (the ones that used to be occupied by hydrogen atoms) are now available to bind other positively charged particles which include various soil nutrients (Hue and Silva, 2000).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Experimental site

The study was conducted from April to September 2014 at Agricultural Research Council (ARC) Experimental Farm, Bien Donné near Paarl in the Western Cape, South Africa (Picture 1). The climate in this region is mediterranean as it receives most of its rainfall during winter, but hot and dry during the summer season. Being in the valley bottom at about 134 meters above sea level and at coordinates; Latitude 33.84274° S and 18.98425° E Longitude and 32 kilometers from the nearest seaboard, this area has cool winter minimum temperatures of approximately 9-11.4°C, but can have hot summer maximum temperatures of 28.2°C without the effects of sea breezes. The rainfall (820mm average per year) is mostly winter frontal type between May to October from the west and south west with dry summers.

Picture 1: Agricultural Research Council (ARC) Experimental Farm, Bien Donné near Paarl in the Western Cape, South Africa (red square-vegetable garden).

3.2 Experimental Design

The experimental design was a complete randomized block design (CRBD) with 4 treatments (Table1) replicated four times (Figure1). Total plots: 4x4=16 plots. Plot size was 3.20m x 3.30m =11m². The experimental field was 11m²x16=176m². The plots were separated with paths of 1m, between replications and 1m between treatments. The edge effect was eliminated by planting border plants on each plot. The following treatments were applied and the procedure that was followed on calculating the amount of compost needed to be applied per plot was adopted from DAFF, (2010) vegetable guidelines bulletin: Table1

Treatments (T)	Winery compost and inorganic applications at different rates
1	control, without compost and inorganic fertilizers
2	inorganic fertilizers 2:3:4 (30) - 5g Zn% before planting and LAN (28) at 3 and 6 weeks cabbage, Swiss chard at 4 and 8 weeks after planting equivalent of 100% inorganic fertilizer application.
3	application of winery waste compost (3485g) equivalent of 100% inorganic fertilizer application.
4	application of winery waste compost (13939g) (400%) equivalent of 100% inorganic fertilizer application.

Table 1: Treatments, application of solid winery compost and inorganic fertilizer

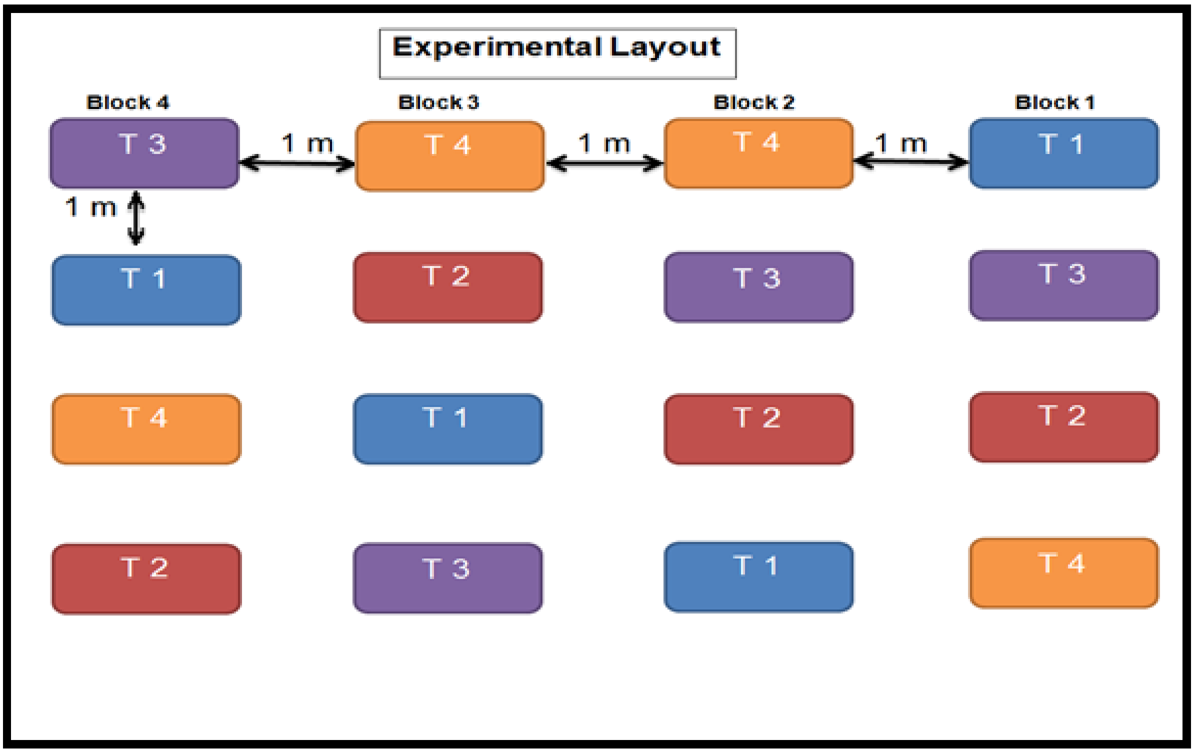

Figure 1: Randomized experimental layout

3.3 Soil Preparation

Land was prepared by a tractor using a disc plough. Garden forks were used to loosen the soil and raking activities were performed to break up clods in to obtain a fine and even surface on the experimental plots (Picture 2). Before planting, three soil samples were taken from experimental block diagonally 0-30cm using an auger. Thoroughly mixed and a representative sample was drawn and taken to laboratory (BEMLAB) for analysis. General soil properties were measured using Inductively Coupled Plasma/Optical Emission Spectrometry (ICP-OES) from Analytical Science, London following manufacturer's instructions. The concentrations of major elements (Na, K, Ca, and Mg) were determined using the ammonium acetate extraction of soil samples. Soil pH (KCl) was measured using pH meter.

At 6 weeks after planting, soil and plants from the borders were sampled from each treatment plot for nematodes extractions and were taken to ARC-INFRUITEC (Stellenbosch) laboratory for analysis. No major nematodes were found, only Crico's and Xiphinema were found in small numbers and declared not harmful by Nematologist. The plots were separated 1m, between replications as well as between treatments.

Picture 2: Soil preparation

3.4 Fertilizer Application

Before application, compost was analyzed for chemical composition. Prior to planting (Picture 3), on the 4th of March 2014, each compost level treatment was applied to each plot and an inorganic fertilizer on treatment 2 was incorporated to a depth of 0-10cm using a folk spade in order to raise pH to between 6.4-6.8, decrease the soil acid saturation and to allow the roots of the plant to have an immediate source of nutrients at root zone. After the fertilizer and compost was worked into the soil, the soil surface was then moistened to prevent them from drying out as sandy soil dry-out quickly.

3.5 Planting

On the 4th of April 2014, healthy and uniformed sized seedlings were transplanted on each treatment block, height of 7-10cm and a number of 5-7 leaves. Spacing for both cabbage and Swiss chard was 50cm between plants and 70 between rows. The seedlings were uprooted carefully from the seedlings trays to avoid any damage to the root system. Transplanting was done early in the morning by hand and thoroughly irrigated after.

Picture 3: Inorganic fertilizers application   Winery waste compost application

Both treatments were applied a month before transplanting, soil surface being moistened to prevent drying of applied treatments.

3.6 Irrigation

Four tensiometers of 0-30cm (length) were installed (one on each block) to guide irrigation schedule during the experiment. Uniform irrigation schedule was followed at all plots to maintain similar moisture condition throughout the growth of plants. The emitter system was used to irrigate three times in a week for 2hours whilst the plants were still young until the winter rainfall (May-October) started. From May to September no irrigation was applied as it was the winter rainfall season.

3.7 Measurements of growth parameters: Swiss chard

3.7.1 Leaf length

Tree plants were tagged and assessed on each plot. Plant height was measured from the 1^{st} vein of the leaf to the tip using a ruler every week for nine weeks from the 2^{nd} week to the 8^{th} week after transplanting.

3.7.2 Plant breadth

Plant breadth was measured from the broadest part of the leaf using a ruler. This was also done from the 2^{nd} week up to the 8^{th} week after transplanting.

3.7.3 Number of leaves

Number of leaves were counted from the 2nd week after transplanting and weekly thereafter. This was done up to 8th week after transplanting. At harvest, the leaves were again counted.

3.8 Measurements of growth parameters: Cabbage

3.8.1 Head diameter

When all cabbage head from each treatment were formed, a Vanier caliper and a meter ruler were used to measure the head diameter.

The leaf chlorophyll content was measured on both crops related to the physiological status of plants using the CCM-200 plus from OPTI-SCIENCE, USA to estimate the chlorophyll content in the leaf tissue.

3.9 Weed, insects and disease control

Weed control was done manually using hand and lady forks in the plots in order to allow water infiltration and aeration to the soil.

A registered pesticide (ALPHA-THRIN 100 SC), in a mixture of (3ml ALPHA, 10ml sunlight liquid and 25l of water) was used to control insects and diseases and was done once every two weeks.

3.10 Harvesting

The plants were harvested for analysis at marketable stage. Cabbage was harvested at 20 weeks and Swiss chard 10 weeks after transplanting.

3.11 Fresh and dry weight determinations

The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid border effect. Three plants from each cultivar (Swiss chard and cabbage) were selected in the middle of each unit plot for the collection of data. The plants were harvested and fresh weight or marketable yield was measured using a platform digital scale FW-150SA, from China.

These plants were then thoroughly washed with distilled water before being chopped. From the three selected cabbage stands, head weight was recorded as untrimmed head weight and trimmed head weight. In South Africa, the hawker market prefers the head with some wrapped leaves while chain stores require the head without wrapped leaves. Untrimmed head is one with wrapped outer leaves while trimmed is a head without wrapped outer leaves (Picture 8). Three selected Swiss chard plants, the leaves and the stem were chopped together whereas the roots were placed on a separate brown paper bags.

3.12 Plant analysis

The plants were oven dried at 70°c for 72hrs (Swiss chard) and 24hrs (cabbage) to determine the dry weight. The dry weights were then analyzed for mineral contents by Bemlab.

3.13 Data analysis

The experimental data from each treatment were subjected to ANOVA and means were compared by tests of least significant differences (LSD), at the confidence level of $p < 0.05$. The statistical software used was SAS, 9.2 (2002-2008).

CHAPTER FOUR
4. RESULTS AND DISCUSSION

4.1 CHARACTERISTICS OF WINERY WASTE COMPOST (WWC) USED IN THE STUDY

The mineral composition of the compost used for the experiment is presented in Table 2. The compost was incorporated 10cm into the soil using folk spade a month before cabbage and Swiss chard were transplanted; in order to allow for the improvement of soil pH (10.30). The mineral analyses from the major nutrients (NPK) indicated that the compost was richer in Potassium (6.57%) followed by Nitrogen (2.49%) and Phosphorus (0.48%). The high level of potassium in the winery waste indicted that the winery mostly like used potassium based cleaning agent as opposed to sodium. Potassium based cleaning agent is preferred to sodium in order to reduce the effect of soil solidity following sodium contamination. The bulk density of compost before application was 737.70kg/m^3 and soil moisture content was 61.70%.

Table 2: Chemical properties of winery waste compost (WWC) used in the study

pH	Moisture %	Density kg/m^3	N %	P %	K %	Ca %	Mg %	Na mg/kg	Mn mg/kg	Fe mg/kg	Cu mg/kg	Zn mg/kg	B mg/kg	C %	Ash %
10.30	61.70	737.70	2.49	0.48	6.57	0.75	0.15	10525.50	48.79	2370.16	26.90	35.27	63.63	14.57	59.050

4.2 SOIL CHEMICAL PROPERTIES BEFORE TRANSPLANTING OF SWISS CHARD AND CABBAGE

Table 3 shows soil chemical properties before transplanting and application of all treatments to different blocks of the experiment. The soil was slightly acidic with a pH of 5.9-6.1; suggesting low soil nutrients with low organic matter and low capacity to store nutrients (Ibrahim and Fadni, 2013). The exchangeable sodium (Na) and magnesium (Mg) were lower than 0.2cmol/kg critical levels considered to be adequate for leafy vegetables except calcium (Ca) with the highest of 4.06 on the top block of the experimental site, thus indicating possible poor soil fertility.

Table 3. Soil chemical properties taken from different blocks (diagonally) before application of treatments

Orchard	Depth (cm)	Soil	pH	P (Mg/kg)	K(Mg/kg)	Exchangeable cations (cmol(+)/kg)		
			(KCl)	BrayII		Na	Ca	Mg
Top Block	0-30	sandy	6.1	33	59	0.07	4.06	0.86
Middle Block	0-30	sandy	6.0	20	62	0.05	3.88	0.92
Bottom Block	0-30	sandy	5.9	23	41	0.07	3.82	0.86

4.3 SOIL CHEMICAL PROPERTIES AFTER TRANSPLANTING AND APPLICATION OF TREATMENTS

Results of the mineral analysis of the soil 2-8 weeks after application of compost and inorganic fertilizer are presented in Table 4. There was a significant ($p<0.05$) drop in soil pH over time in the untreated control, indicative of a typical characteristics of sandy soil. There was probably a continuous leach of base forming minerals in the soil over time. The application of 400% WWC significantly ($p<0.05$) raised soil pH after six weeks compared with the control. Unlike the compost, the application of inorganic fertilizers significantly ($p<0.05$) depressed soil pH by 3.54%; indicating a positive effect of compost in the alleviation of soil pH compared with mineral fertilizer. In general, the results indicated increase in pH of the soil along compost concentration gradient over time. Considering the high pH of the compost (10.30) the improvement in the pH of the soil, eight weeks after application is not unexpected. This study positively correlates with early findings where acidic soil was corrected over time using compost from winery waste sources on a few species (Bustamente *et al*., 2008a; Nóvoa-Muńoz *et al.*, 2008).

Improved soil fertility through the application of fertilizers is an essential factor enabling the world to feed billions of people that are added to its population (Okwuagwu et al., 2003). As expected, the application of mineral fertilizer showed significant ($p<0.05$) increase in soil P compared with the other treatments during the second week (Table 4). However, between week 4 and 6, WWC picked up significant ($p<0.05$) speed above inorganic fertilizer, thus making P available to the soil than NPK mineral fertilizer. In this study, P from WWC source dipped by 12.4% between week 6 and 8; indicating a possible leaching, fixation in soil or uptake by the test crops. Generally, the result showed significant ($p<0.05$) increase in P availability along concentration gradient from week 4 to 8 as affected by WWC application. Bustamente *et al*. 2010, in a study on application of winery and distillery waste composts reported that high soil P concentration might be due to the use of grape stalk; a waste characterized by a high content of phenolic compounds especially tannins which improve P availability by interacting with metal oxides. Similar results were reported by Civeira (2010). This finding reported that municipal solid waste compost effectively supply P to soil with P concentration increasing with increasing application rates.

In the present study, the results indicated a significant ($p<0.05$) drop in soil K content by 21% over time on amended soil with inorganic fertilizer treatment. Among soil types, K deficiency occurs more often in sandy soil than in clayey soils (Hue and Silva, 2000). The decrease of soil K in the treatment subjected to inorganic fertilizer might be due to low amount of organic matter and thus high rate of leaching. Potassium is generally a highly mobile soil and the combination of its occurrence in a sandy soil under high level of winter rainfall experienced during the experiment can only accelerate the rate of K leach through the soil profile.

The application of WWC at 300 and 400% significantly ($p<0.05$) raised the soil K by 54.93 and 73.06% respectively. The increase in soil K concentration might be due to the higher K concentration contained in WWC. Considering the high K of the compost (6.57%), the significant increase in soil-available K in the winery waste treatments was expected as the compost used was very rich in total K (Table 2). The increase in available K in the compost treatments might be due to high microbial activity brought by the addition of organic residues, which might speed up potassium cycling. These findings are in line with the results by Bustamente *et al*. 2010, which reported that high soil K concentration might be due to a high proportion of winery and distillery waste products that are characterized by high K concentrations.

Research results show that there were no significant differences in soil Ca over time and the mean values varied from 2.7 to 3.2 during the period of the experiment (8 weeks). Calcium, an essential part of plant cell wall structure, provides for normal transport and retention of other elements as well as strength in the plant (Singh *et al.,* 2013). Despite the fact that all treatments were significant, Ca from WWC (400%) source dipped by 7.4% between week 2 and 4 and a slight drop between week 6 and 8; indicating a possibility that winter rainfall may have leached dissolved organic matter from sandy soil, thus inhibiting fixation or uptake by the test crops.

From 4-8 weeks, high soil Ca concentrations from WWC (100%) were recorded compared to inorganic treatment that showed the lowest soil Ca concentration. Nutrient, Ca, depletion in sandy soils may be a consequence of leaching as described by Masarirambi *et al*., 2010. Additionally, NPK fertilizers do not improve the water holding capacity of sandy soil. The reason for inorganic treatment having lower concentration might be the available nutrients from inorganic fertilizer that are quickly absorbed and then drains quickly into sandy soil following high level of leaching in sandy soils (Masarirambi *et al.,* 2010).

Civeira (2010), demonstrated that increasing compost application does not always increase organic carbon and nutrients content of the soil. Another study by Dikinya and Mufwanzala (2010), indicated that high concentrations of Ca were similarly observed in all soil types. According to farmer's weekly (2007), South African soils are generally deficient in calcium with as much as 95% and thus explaining the low levels of Ca observed in the soil.

There was a slight drop in soil Na over time in control and soil amended with inorganic fertilizer. The application of WWC at 300 and 400% significantly ($p<0.05$) raised soil Na as compared to control and inorganic fertilizer treatment. Considering the high Na concentration of WWC (10525.50mg/kg) incorporated into the soil, the subsequent increase in soil Na levels eight weeks after application is explainable. In general, the result indicated increase in Na accumulation in the soil along concentration gradient over time. The increased Na concentration in WWC treated soil implies that greater micro nutrients are released into the soil as result of applying Na rich compost, thus improving Na availability in sandy soil that are characteristically Na poor.

The effects of the treatment on Mg values were not so prominent, suggesting that concentrations of nutrients are less essential characteristics of the soil or small portion of nutrients were readily available on the soil. However, measurements at 6th week showed higher Mg concentration in the control treatment and the reason might be the nutrients in the applied treatments were not readily available to the soil. The Mg result contradicts the findings of Dikinya and Mufwanzala (2010), who observed an increasing ratio of cations including Mg when different applications of compost were applied to the soil.

Table 4. Mineral analysis of the soil samples over 8 weeks following treatments application

Harvest time (Week)	Treatment (T)	pH KCl	P mg/kg	K mg/kg	Ca cmol/kg	Na cmol/kg	Mg cmol/kg
2	T1	5.90bc	25.75fg	51.25g	3.07a	0.07bc	0.67ab
2	T2	5.65cde	40.00ab	79.75efg	2.90a	0.07cd	0.60b
2	T3	5.92bc	24.00g	64.00fg	3.04a	0.07bc	0.65ab
2	T4	5.90bc	27.00fg	111.75de	3.10a	0.08ab	0.67ab
4	T1	5.68cde	27.75efg	53.50g	2.74a	0.06cde	0.63ab
4	T2	5.40de	28.25efg	68.00fg	2.93a	0.06de	0.62b
4	T3	5.70cd	25.75fg	87.50ef	3.06a	0.07cd	0.68ab
4	T4	6.05abc	32.25bcd	321.50c	2.87a	0.08a	0.62b
6	T1	5.95bc	34.25bcde	53.75g	3.09a	0.07cd	0.72a
6	T2	5.28e	32.50cdef	61.50fg	2.98a	0.06e	0.59b
6	T3	6.03abc	26.25fg	140.25d	3.19a	0.07cd	0.66ab
6	T4	6.43a	42.50a	362.0b	3.17a	0.08ab	0.68ab
8	T1	5.70cd	26.25fg	56.25fg	3.06a	0.06cde	0.63ab
8	T2	5.45de	32.50cdef	63.00fg	2.96a	0.06cde	0.59b
8	T3	5.93bc	29.25defg	142.00d	3.17a	0.06cde	0.67ab
8	T4	6.30ab	37.25abc	414.75a	3.14a	0.08ab	0.65ab

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at *$p<0.05$*. LSD=Least significant difference

4.4 EFFECTS OF TREATMENTS ON LEAF MORPHOLOGY AND CHLOROPHYLL CONTENT OF SWISS CHARD

Leaf count is an important parameter to consider when evaluating the yield performance of Swiss chard. The results of the interaction between harvest time and the different levels of treatment on the growth parameters and chlorophyll content of Swiss chard is presented in Table 5. Considering number of leaves, a significant ($p<0.05$) increase in number of leaves was recorded over time during the experiment. Consistent leaf increase was observed from all treatments during the experiment with plants derived from WWC showing high significant ($p<0.05$) number of leaf compared to plants subjected to inorganic fertilizer and control.

At 2 weeks after transplanting, plants under inorganic fertilizer treatment showed slight insignificant increase in leaf number compared to other treatments. Nutrients from inorganic fertilizers are readily available, absorbed and utilized by plants. For instance, nitrogen present in commercial fertilizer is associated with high photosynthetic activity and vegetative growth (Miller and Donahue, 1990). These results are in agreement with findings by Masarirambi *et al.* (2010), who reported that chemical fertilizers used in conventional agriculture contain just a few minerals, which dissolve quickly in damp soil and give the plants large doses of minerals hence improving quality and number of leafy vegetables. Hasan and Solaiman (2010), also reported higher number of leaves in cabbage when inorganic fertilizer was applied as source of fertilizer.

Unlike inorganic fertilizer, compost derived from plant residues need to be broken down by microorganisms before it can release nutrients and therefore it is known to release nutrients slower than other organic fertilizer sources (Mbatha, 2008). In a similar way, Lima *et al.* (2004), evaluating the behavior of vegetables cultivated in urban waste organic compost, observed an improvement in the soil fertility, number of leaf and an increase in vegetable production.

The application of WWC stimulated vegetative growth by increasing the number of leaves (Picture 4). This is particularly prominent between week six and eight with 100% WWC showing overall superiority over other treatments at the eighth week. The slow release of nutrients from WWC may have caused eventually better performance of WWC after eight weeks. In addition, compost lead to better root development that result in nutrient uptake by the plant; thus improving crop productivity. This statement is supported by Suge *et al.* (2011) affirmed that addition of organic fertilizer encourages good root development and lead to higher yields. In respect of foliar yield, the current result appears to be in agreement with Suge *et al.* (2011) reports.

Picture 4: Swiss chard in one of the (WWC) experimental plots

In general, there was no significant (*$p<0.05$)* increase in leaf length, breadth and area from week four to week eight (table 5). However, at treatment levels leaf length and leaf area showed significant yield increase by WWC compared with the control and inorganic fertilizer between 6-8 weeks of the study. In this study, WWC (100%) showed as superior 36.5% yield increase for leaf length and about three times yield increase (*$p<0.05$)* for leaf area compared with the mineral fertilizer (table 5). Surprisingly, 100% WWC recorded the highest leaf yield in this study with more than three times yield increase for leaf area compared with 400% WWC. Civeira (2010) indicated that increasing compost application does not always increase organic C and nutrients content that lead to improved leaf morphology. These results also corroborate the findings of Khan *et al. (*2007), who reported that green tea waste-rice bran compost increase the leaf length of spinach under different compost applications. Similar results have been reported by Masarirambi *et al.* (2010), when studying the effects of organic fertilizers on growth of red lettuce.

In summary, the results of the present study demonstrated superior performance (*$p<0.05$)* of WWC compared with the control and mineral fertilizer. Similar results have been reported with wheat (Abedi *et al*. 2010), lettuce (Masarirambi *et al.*, 2012), red lettuce (Masarirambi *et al*., 2010), and eggplant (Suge *et al.,* 2011).

In respect to leaf chlorophyll content, the study does not show any significant (*$p<0.05$)* difference due to treatment effects (Table 5). However, there was a progressive increase in leaf chlorophyll content from week 2 to week 8 with a significant ($p<0.05$) increase recorded between week 2 and 4. In general, inorganic fertilizer showed superior ($p<0.05$) performance in chlorophyll content compared with other treatments except for WWC (400%) at week 8. Pigmentation in plants is related to chlorophyll content in the leaf (Mitic *et al*., 2013).

Increasing chlorophyll content tends to be related to photosynthetic activity and ultimately crop yield which tends to increase under organic manure (Siavoshi and Laware 2013). The positive influence of WWC on chlorophyll content in the present studies is reported in several studies (Bokhtiar and Sakurai, 2005; Liu *et al.,* 2013 and Siavoshi and Laware, 2013).

Table 5. The growth parameters and chlorophyll content of Swiss chard over 8 weeks following treatments application

Harvest time (Week)	Treatment (T)	Leaf count (no.)	Leaf length (cm)	Leaf breadth (cm)	Leaf area (cm)	Chlorophyll
2	T1	3.50h	6.42fg	4.18fg	29.97ef	8.74f
2	T2	3.92gh	5.41g	3.21g	19.15f	7.93f
2	T3	3.63h	6.96efg	4.70efg	38.75ef	8.59f
2	T4	3.30h	6.78efg	4.20fg	31.71ef	10.82f
4	T1	4.58gh	7.11efg	4.86efg	39.24ef	17.22de
4	T2	4.00gh	6.71fg	4.20fg	30.87ef	16.87de
4	T3	5.51fg	8.62cdef	5.98cdef	61.68cde	18.67de
4	T4	4.75gh	8.46cdef	5.45def	52.04def	19.50cde
6	T1	6.58ef	8.10def	5.61cdef	52.23def	13.66ef
6	T2	7.49de	8.14def	5.11defg	46.44def	17.00de
6	T3	8.28d	10.72abc	7.56abc	93.34bc	17.25de
6	T4	7.75de	10.43abcd	7.04bcd	81.84bcd	21.50cd
8	T1	8.71cd	8.78cdef	6.51bcde	65.45cde	25.06bc
8	T2	10.39b	9.24bcde	6.22bcdef	68.22cde	32.35a
8	T3	12.31a	12.82a	9.10a	135.44a	22.56cd
8	T4	10.11bc	11.57ab	8.21ab	109ab	28.65ab

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at *p<0.05*. LSD=Least significant different.

4.4.1 Marketable Yield, fresh and dry leaves of Swiss chard

The marketable yield of Swiss chard from all treatments plots including control showed no statistical significant difference (Table 6). These results are in line with the findings of Rippy *et al.* (2004), on tomatoes studies. Herencia *et al*. (2007), also found that there was no significant difference between organic and mineral fertilizer treatments, although the harvest duration was relatively short compared to Swiss chard (Rippy *et al.,* 2004). Masarirambi *et al.* (2012), reported that marketable yield of lettuce from plots applied with 40 t/ha kraal manure was not significantly ($p>0.05$) different from yield of lettuce from plots applied with 60 t/ha kraal manure or 40 t/ha chicken manure. Zhai *et al.* (2009), reported that high K and Na from swine compost may have influenced plants from compost treatments leading to lower yields, which might be the case in this study.

The results of fresh leaves (weight) revealed that fresh weight was significantly ($p<0.05$) influenced by different treatments applied (Table 6). Statistically, progressive increase of fresh leaf weight was observed with increased concentration of WWC. These results are in line with the findings of Lima *et al.* (2004), who observed an improvement in soil fertility and vegetable production when evaluating the behavior of vegetables cultivated in urban waste organic compost. Independently, this observation is in agreement with studies by Masarirambi *et al*. (2012), who reported that lettuce grown in soil supplied with organic fertilizers showed better vegetative growth as compared to lettuce grown using inorganic fertilizers.

However, statistical analysis showed no significant difference on all treatments for dry leaves (weight) of the Swiss chard (Table 6). In general, treatments had no influence on dry leaves of Swiss chard. Similar results were found by Miceli and Miceli, (2014) who observed that dry matter percentage was not influenced by nitrogen fertilization level. Lima *et al.* (2004), made similar observations and concluded that the urban waste application had no significant difference on soil fertility and thus, did not improve the production of dry matter.

Table 6: Marketable yield, fresh and dry leaves of Swiss chard (g)

Treatment	Marketable Yield (same replicated number of samples)	Fresh leaves weight (one bunch sample)	Dry leaves weight (one bunch sample)
(T)	(g)	(g)	(g)
T1	760.00a	44.64b	0.76a
T2	1360.00a	89.00a	1.36a
T3	1360.00a	95.56a	1.36a
T4	1360.00a	90.37a	1.40a

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at $p<0.05$. LSD = Least significant different.

4.4.2 Macro and micro nutrient contents of Swiss chard leaves as influenced by mineral fertilizer and different levels of winery waste composts

Mineral fertilizer showed significant ($p<0.05$) 12.3% and 35.8% yield increase for N and Mg respectively compared with the best yields in the other treatments (Table 7). In addition, Swiss chard accumulated significantly ($p<0.05$) high P and K in its leaves compared with the other treatment while Ca and Na were significantly ($p<0.05$) higher in the control treatment. Nitrogen is recognized as one of the major factors influencing yield of vegetables and quality of crop (Kolota and Czerniak, 2010). The superior performance of inorganic fertilizer in terms of the delivery of N to plant tissue over other treatments suggests that the inorganic fertilizer contain readily dissolvable N in the soil, which are absorbed by the vegetable (Masarirambi *et al.* (2010), hence improving N yield in Swiss chard (Miceli and Miceli, 2014).

According to Zhai *et al.* (2009), composts are not generally high in total nutrients and they are slowly released. the result showed that the compost at 100 or 400% were not sufficient enough to supply N demands for the species over the 8 weeks experiment compared with inorganic fertilizer. Therefore, the low N in the leaf treated with WWC was due to slow mineralization rate and low N content of the compost used in the study. According to Citak and Sonmez, (2009) Mg is generally high in all green vegetables because of its association with chlorophyll. Considering the results of the present study, Mg yield in the leaf of Swiss chard in response to inorganic fertilizer correlates with the superior performance of inorganic fertilizer on chlorophyll reading compared with the other treatments (According to Citak and Sonmez, (2009); Pokluda and Kuben, (2002) consider Swiss chard as a vegetable more tolerant to higher salinity and accumulates higher levels of sodium in its tissues compared with other leafy vegetables.

The accumulation of Na in the tissue of Swiss chard under control treatment is therefore not surprising as past studies have indicated high affinity of the species to Na (Pokluda and Kuben, 2002). Finally, the enhanced level of Ca in the control treatment could be explain by the absence of elements like K which could have compete with Ca uptake compared with the WWC treated plots. In conclusion, it could be said that appropriate mixture of WWC and inorganic fertilizer could provide the most desirable quality product to final consumer.

Table 7: Macro and micro nutrient contents of Swiss chard leaves as influenced by mineral fertilizer and different levels of winery waste composts

TREATMENTS (T)	Swiss chard leaf analysis					
	N	P	K	Ca	Na	Mg
T1 (Control-0%)	3.51b	0.37bc	7.44bc	1.34a	20702a	0.88b
T2(Inorganic fertilizer)	4.22a	0.36c	6.48c	1.42a	10169c	1.37a
T3 (Compost-100%)	3.70b	0.44b	8.19b	1.11b	16195b	0.81b
T4 (Compost-400%)	3.61b	0.64a	9.64a	0.85c	18477ab	0.82b

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at *$p<0.05$*. LSD=Least significant different

4.5 EFFECTS OF TREATMENT ON GROWTH PARAMETERS AND CHLOROPHYLL CONTENT OF CABBAGE

There was a progressive increase in cabbage diameter over time with a significant ($p<0.05$) yield increase recorded at 2 weeks interval irrespective of the fertilizer type (Table 8). An analysis of the interaction between the treatment levels and harvest time revealed that inorganic fertilizer and 400% WWC significant ($p<0.05$) perform better at eight weeks than the other treatment levels and harvest time respectively. Similarly, inorganic fertilizer consistently recorded significant ($p<0.05$) higher chlorophyll content than the other treatments between weeks 4 and 8 (Table 8).

The outcome of this study is in agreement with several reports on the use of organic and inorganic sources of fertilizer on the growth and yield of cabbage where comparison and combination of these sources are documented to remarkably influence the production of cabbage (Olaniyi and Ojetayo, (2011); Hasan and Solaiman, (2012); Pour *et al*. 2013). Due to the early and steady release of inorganic fertilizer, minerals are made available to manufacture more chlorophyll and develop site for photosynthesis compared with organic fertilizer (Siavoshi and Laware, 2013).

In general, the result indicated better performance of inorganic fertilizer in terms of chlorophyll content compared with WWC. However, unlike the reports on cabbage, Bokhtiar and Sakurai, (2005) and Liu *et al*. (2013), documented significant ($p<0.05$) better chlorophyll contents in organic fertilizer compared with inorganic in Sugarcane and Pineapple respectively; suggesting that the chlorophyll content under different fertilizer types may be species dependent.

Table 8. The growth parameters of cabbage over 8 weeks following treatments application

Harvest time (Week)	Treatment (T)	Cabbage head (cm)	Chlorophyll
2	T1	8.08i	19.46g
2	T2	10.92gh	16.67g
2	T3	8.32i	20.32fg
2	T4	10.41h	21.86fg
4	T1	10.67gh	42.89e
4	T2	13.22ef	59.53cd
4	T3	10.50h	34.04ef
4	T4	13.23ef	44.31e
6	T1	1350def	41.63e
6	T2	15.30bcd	74.36b
6	T3	12.61fg	44.60e
6	T4	14.63cdef	45.53de
8	T1	16.40bc	70.63bc
8	T2	18.70a	95.22a
8	T3	16.25bc	75.12b
8	T4	18.63a	74.13b

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at *p<0.05*. LSD=Least significant different

4.5.1 Marketable yield, fresh and dry leaves of cabbage

Statistical results on the current study have showed no significant difference between treatments, except for control which showed low mean value (Table 9). The lower values obtained in the current study can probably be attributed to the lower fertility level of the sandy soil, which had not received any fertilizer in the years prior to the experiment. Other reason might be the winter rainfall and cold weather that reduced the influence of treatment on marketable yield, resulting in differential effect of WWC and inorganic fertilizer.

However, inorganic fertilizer treatment showed high mean value followed by 400% then 100% WWC treatment.

The results of the current study are in agreement with the results of del Amor, (2007) who observed no significant difference in total marketable yield of sweet pepper when comparing organic and mineral fertilization. Hargreaves *et al. (*2009), also reported same results on strawberries on their studies on the effect of municipal solid waste compost and tea compost on mineral elements uptake and fruit quality. These results suggest that nutrients derived from both treatments (inorganic fertilizer and WWC) were equally available to the crops and have a positive influence on cabbage yield.

Report by Siavoshi and Laware (2013), found that organic manure application with chemical fertilizers increased yield more than chemical fertilizers alone. The fresh cabbage leaves were significantly different ($p<0.005$) between treatments (Table 9). The higher fresh leaves mean was derived from 100% followed by 400% WWC treatment. These results indicate clearly that WWC had a positive influence on cabbage fresh leaves (weight). On dry leaves (weight), statistical results showed that there is no significant ($p<0.05$) difference between treatment means (Table 9).

Table 9: Fresh and dry yield component of cabbage

Treatment (T)	Yield (Kg)	Fresh leaves (one bunch sample) (g)	Dry leaves (one bunch sample) (g)
T1 (Control-0%)	910.00b	300.30c	33.26a
T2(Inorganic fertilizer)	2010.00a	301.21b	30.95a
T3 (Compost-100%)	1740.00a	301.45a	34.69a
T4 (Compost-400%)	1930.00a	301.35ab	31.98a

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%). Mean along the same column with the same letter are not significantly different at *p<0.05*. LSD=Least significant different

4.5.2 Mineral analysis of market size cabbage

The macro and micronutrients contents of cabbage are presented in Table 10. As expected for cabbage, inorganic fertilizer showed significant ($p<0.005$) N accumulation in the tissue of cabbage compared with the treatments followed closely by WWC with a significant ($p<0.005$) yield drop of 15.5% (WWC 100%) and 10.6% (WWC 400%) respectively. Similarly, inorganic fertilizer significantly ($p<0.005$) improved the Na content in cabbage compared with the other treatments. The 400% WWC favoured significant (*p<0.005*) accumulation of P and K in the tissue of the species while WWC 100% also significantly (*p<0.005*) outperformed inorganic fertilizer for K by 20.1%. The results of the current study also indicated negative correlation in the accumulation of Ca and Mg along concentration gradient; as the control treatment showed significant (*p<0.005*) Ca and Mg yield increase compared with the other treatments. In both minerals (Ca and Mg), WWC 100% recorded significant (*p<0.005*) yield increase than WWC 400%.

Nitrogen is a major mineral required for quality production of vegetables (Kolota and Czerniak, 2010). The analysis of the mineral contents in the WWC used for this study indicated that the N content is very low which also affected N content in Swiss chard. The N content in the WWC is not enough for optimum crop yield. Also being a vegetable species, the rate of release of N from WWC could be too slow for the vigorous rate of N required by cabbage during the study. The steady release of the N into soil solution could have encouraged uptake and ultimately improved N content in the tissue of cabbage (Masarirambi *et al.,* 2010; Miceli and Miceli, 2014).

The increase in the P and K content of cabbage following increasing concentration of WWC is supported by Liu *et al.,* (2013) who reported increased accumulation of N, P and K in pineapple on a pineapple waste compost. In a related study, Hargreaves *et al.* (2009), reported that increasing the application rates organic fertilizer increased extractable contents of many mineral elements, thereby making them available to crop. In the present study, Ca, K and P increased along WWC concentration gradients.

Overall, Ca and Mg where better absorbed in the control treatment than the other fertilizer treatments. This could be explained by the influence of K ions competing for space with Ca and Mg which are larger than K, monovalent element; and the current result was supported by early finding by El-Desoki *et al.,* (2005) on broccoli. The superior performance of inorganic fertilizer application in terms of Mg accumulation positively correlates with chlorophyll content. Early studies reports positive association between chlorophyll content and Mg accumulation in crop tissue (Siavoshi and Laware, 2013).

Table 10: Mineral analysis of market size cabbage

TREATMENTS (T)	Cabbage analysis					
	N	P	K	Ca	Na	Mg
T1 (Control-0%)	1.69c	0.20c	2.20c	1.83a	262.25b	0.21a
T2(Inorganic fertilizer)	2.26a	0.27b	2.10c	1.20bc	604.75a	0.19ab
T3 (Compost-100%)	1.91b	0.29b	2.63b	1.31b	211.00b	0.16b
T4 (Compost-400%)	2.02b	0.37a	3.40a	0.86c	187.25b	0.12c

T1: Control; T2: Inorganic fertilizer; T3: WWC (100%); T4: WWC (400%)

Mean along the same column with the same letter are not significantly different at *p<0.05*. LSD=Least significant different

CHAPTER FIVE
5. CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The current study showed that both winery waste compost and inorganic fertilizer have independent roles to play in soil amendment, growth parameters, yield and mineral contents of the crops tested; but none can supply all nutrients for comprehensive yield quality of both cabbage and Swiss chard. An interesting finding of this research is that no statistically significant ($p<0.05$) differences in yield were recorded between treatments (inorganic fertilizer and WWC) on both Swiss chard and cabbage. According to Zhai *et al.* (2009), composts generally are not high in total nutrients and they are usually released slowly (Tables 7and10). The current study showed that compost at 100 or 400% were not sufficient enough to supply plant leaf N demands for the period of 8 weeks. The release of nutrients may necessitate earlier application of compost prior to planting. Arvanitoyannis *et al*. (2006), reported that the compost derived from pressed grape skin, produced one of the best qualities composts both in terms of its physicochemical characteristics and agronomic value. The use of WWC as an amendment in agricultural soils can be considered as an option for conserving organic matter levels in soils and improving the fertility of sandy soils.

The real economic motivations to use winery waste compost as soil amendment need to be introduced with greater emphasis among grape or wine farmers where such waste materials are generally ample. The reuse of winery waste that would otherwise be buried in landfills will have immense environmental benefit when not used excessively. Inorganic fertilizers are generally becoming very expensive for resource poor farmers (Venter, 2011). Alternative use of WWC for soil amendment can benefit the soil, more economical nutrient source for the production of leafy vegetables. Additionally, it would be more favourable for the environment.

Growth parameters, amounts of nutrients taken by the plant and chlorophyll content of both crops were affected by WWC and inorganic fertilizer. Based on the achieved results, the importance of WWC application for assurance of optimum yield on both crops can be confirmed. The results confirm good possibilities of production of quality Swiss chard and cabbage in Bien Donné conditions accompanied by satisfactory yield levels and mineral quality only if further study is conducted to measure the combination of WWC and mineral fertilizer in the production of both vegetables.

From the data, soil pH values were not modified by application of WWC but a decrease was observed with inorganic fertilizer amended soil. However, a significant increase of exchangeable Na with WWC application was noticed. Based on the analysis of the compost, amounts of essential nutrients were approximately equivalent to those in inorganic fertilizer were added to the soil during the duration of the experiment.

There is scarcity of information on use of solid winery waste compost to grow vegetables. More research is required to combine WWC with inorganic fertilizers in both short and long term crop rotation system. These results should be interpreted with caution as they are from an individual soil type and short term experiment. However, they do provide insight for the direction of future research.

5.2 RECOMMENDATION

It would also be interesting to study plant quality parameters such as taste, appearance, storability, susceptibility to bugs and disease as they are all important criteria to the consumer. In addition, small holder farmer who cannot afford mineral fertilizer may utilize WWC as an alternative for soil amendment at 100% application which is economical and effective nutrient application for growth and development of cabbage and Swiss chard. Higher application (above 100% equivalent application rate for mineral fertilizer) level might have adverse effects in future.

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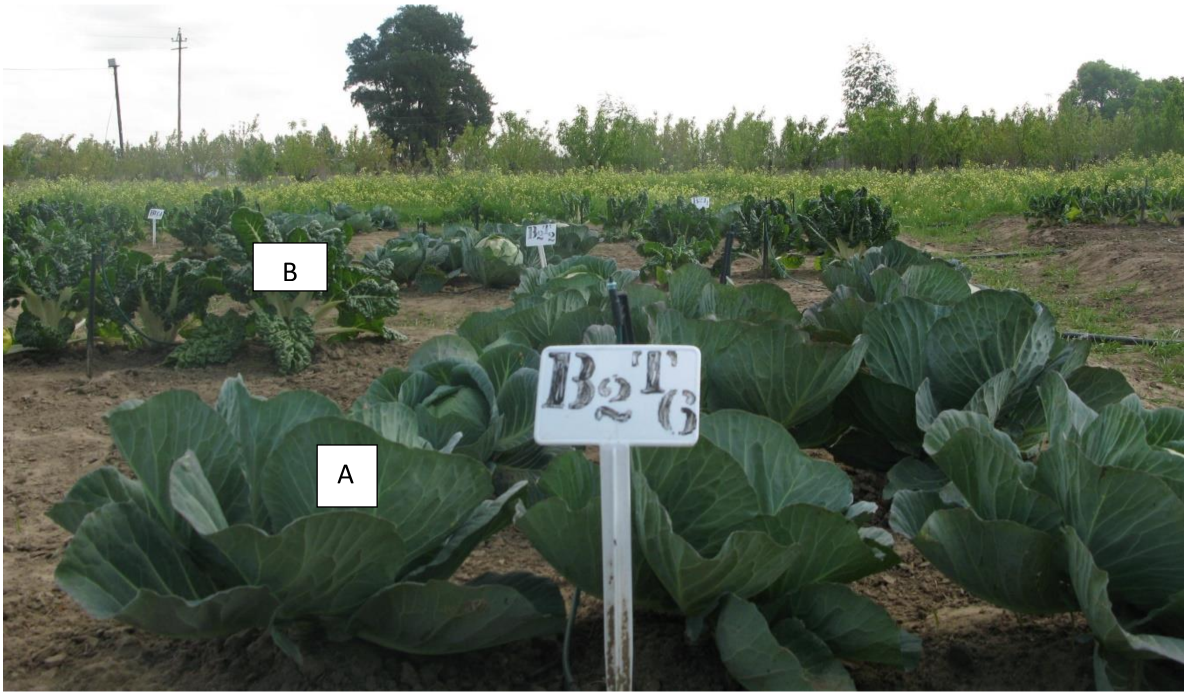
APPENDICES

APPENDIX A: Section of the experimental layout showing cabbage and Swiss chard in different plots (A: cabbage; B: Swiss chard).



The leaves of the crops (cabbage and Swiss chard) are consumed by humans which can be prepared into varying food types such as "imifino" likely to be eaten by the African people of the Eastern Cape and leaves can also be fed to domesticated

<u>APPENDIX B:</u> Butterfly on cabbage (3 weeks after transplant)

The cabbage plants attract a number of insect pests at different stages of the plant growth due to their nutritious and flourishing nature.

<u>**APPENDIX C:** P-Values for Anova on soil parameters</u>

Source	d.f.	pH (KCl)	P BrayII mg/	K kg	Exchangeable cations (cmol(+)/kg) Ca	Na	Mg
Block	3	0.9536	<.0001	0.1077	0.7464	0.082	0.1489
Treatment	3	<.0001	<.0001	<.0001	0.7024	<.0001	0.0293
Time	3	0.1988	0.0305	<.0001	0.6763	0.1567	0.6168
Trt_Time	9	0.2123	0.0017	<.0001	0.8462	0.6476	0.7469

APPENDIX D: P-Values for Anova on Swiss chard growth parameters

Source	d.f.	Leaf count	Leaf length	Leaf breadth	Leaf area	Chlorophyll
Block	3	0.1642	0.8159	0.2341	0.2577	0.9618
Treatment	3	0.0013	0.0004	0.0006	0.0003	0.0422
Time	3	<.0001	<.0001	<.0001	<.0001	<.0001
Trt_Time	9	0.1483	0.8344	0.9506	0.6545	0.1924

APPENDIX E: P-Values for Anova on Swiss chard yield and leaves

Source	d.f.	Yield	Fresh leaves weight	Dry leaves weight
Block	3	0.6973	0.6744	0.6154
Treatment	3	0.2606	0.0477	0.2341

APPENDIX F: P-Values for Anova on Swiss chard mineral analysis

Source	d.f.	N	P	K	Ca	Na	Mg
Block	3	0.0114	0.7726	0.3473	0.0448	0.9216	0.7578
Treatment	3	0.0026	<.0001	0.0016	0.0001	0.0003	<.0001

APPENDIX G: P-Values for Anova on growth parameters of cabbage

Source	d.f.	Cabbage head	Chlorophyll
Block	3	<.0001	0.0884
Treatment	3	<.0001	<.0001
Time	3	<.0001	<.0001
Trt_Time	9	0.9983	0.0215

APPENDIX H: P-Values for Anova on cabbage yield and leaves

Source	d.f.	Yield	Fresh leaves	Dry leaves
Block	3	0.0017	0.0007	0.7764
Treatment	3	0.0135	<.0001	0.5809

APPENDIX I: P-Values for Anova on cabbage analysis

Source	d.f.	N	P	K	Ca	Na	Mg
Block	3	0.1888	0.1872	0.2239	0.0193	0.9608	0.0243
Treatment	3	0.0017	<.0001	<.0001	0.0016	0.0003	0.0004