INFLUENCE OF ORGANIC FERTILISERS ON THE YIELD AND QUALITY OF CABBAGE AND CARROTS

by

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DECLARATION

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26/11/2008

Alice Nompumelelo Mbatha **Date**

THE INFLUENCE OF ORGANIC FERTILISERS ON YIELD AND QUALITY OF CABBAGE (*Brassica oleraceae* var. *capitata L.*) AND CARROTS (*Daucus carota* L.)

ABSTRACT

The use of organic fertiliser as an alternative to inorganic fertiliser increased among subsistence farmers in rural areas in KwaZulu Natal. No clear recommendations exist for the application of different organic fertilisers on vegetables. Two field trials were conducted at Umsunduze Training Centre, KwaZulu Natal during the 2005 and 2006 seasons. The effect of three different organic fertilisers (chicken, kraal manure and compost) were investigated on the growth, yield and quality of cabbage cv. Conquistador and carrots cv. Kuroda. Four application rates were used for each organic fertiliser (chicken manure: 0, 6.25, 12.5 and 25 kg 10 m^{-2}; kraal manure: 0, 12.5, 25 and 50 kg 10 m^{-2}; compost: 0, 25, 50 and 100 kg 10 m^{-2}). Each treatment combination was replicated four times. Organic fertilisers were incorporated into the soil one month before planting. Number of leaves and plant height were measured for the first 8 weeks after planting for both crops. Fresh and dry mass was determined at harvesting for both cabbage and carrots. Cabbage head and carrot shoulder diameter, carrot root length and carrot root total soluble solids were measured at harvesting. Both crops were graded (cabbage into 3 and carrots into 5 classes) according to their external appearance. After harvesting, soil analysis (2005 and 2006) and plant analysis (2006) were done for both crops.

Chicken manure applied at 12.5 or 25 kg 10 m^{-2} showed a significant increase in the growth rate of cabbage during the first 8 weeks after transplanting in both seasons. During 2005, fresh mass of cabbage that received 12.5 or 25 kg 10 m^{-2} chicken manure was significantly higher and of better quality than the other organic fertiliser treatments. In 2006, the fresh mass and quality of cabbage that received 50 kg 10 m^{-2} kraal manure, 25 kg 10 m^{-2} chicken manure or 100 kg 10 m^{-2} compost was significantly higher than the other organic treatments. Dry mass also significantly increased when 25 kg 10 m^{-2} chicken manure was applied. Compost significantly increased the nitrogen, phosphorus, potassium, sulphur and calcium content, while kraal manure significantly increased the phosphorus, potassium and magnesium content of the soil after two years of application. It was in most cases

the two highest application rates (Rate 2 and 3) that significantly influenced the chemical properties of the soil. Only chicken manure significantly influenced the nitrogen content of cabbage heads.

Carrot plants that received chicken and kraal manure at Rate 2 or 3 produced the most number of leaves while the tallest carrot plants were obtained where 25 kg 10 m^{-2} chicken manure or 50 kg 10 m^{-2} compost was applied, at 8 weeks after planting. Different organic fertilisers and application rates did not significantly influence the fresh mass and root length of carrots. Dry mass of carrots that received 25 kg 10 m^{-2} chicken manure, 50 kg 10 m^{-2} kraal manure or 25 kg 10 m^{-2} compost was significantly greater than plants that did not receive any fertiliser in 2006. High organic fertiliser rates (Rate 3) significantly increased shoulder diameter. In 2005, chicken manure and compost significantly decreased total soluble solid content of carrots. In 2006, the highest total soluble solid content was obtained with 12.5 kg 10 m^{-2} chicken manure. An increase in the organic fertiliser rate promoted the development of hairy carrots in 2005 and carrots that received compost (Class 3) was of a poorer quality than those that received chicken or kraal manure (Class 2) in 2006. Compost significantly increased the phosphorus, potassium content and NIRS organic matter of the soil and kraal manure only significantly increased the sulphur content of the soil after two years of application. Chicken manure (25 kg 10 m^{-2}) and 100 kg 10 m^{-2} compost significantly increased the nitrogen content of carrot roots, while the calcium content was significantly lowered where chicken manure was applied. Kraal manure significantly increased the iron content and 6.25 kg 10 m^{-2} chicken manure increased the total carbon content of carrots.

UITTREKSEL

Bestaansboere in die plattelandse gebiede van KwaZulu Natal gebruik al hoe meer organiese bemesting as ‘n alternatief vir anorganiese bemesting. Daar bestaan geen duidelike aanbevelings vir toedieningspeile van organiese bemesting op groente. Twee veldproewe is in 2005 en 2006 by die Umsunduze Opleidingssentrum, in KwaZulu Natal uitgevoer. Die invloed van drie organiese bemestingstowwe (hoendermis, kraalmis en kompos) op die groei, opbrengs en kwaliteit van kool cv. Conquistador en geelwortels cv. Kuroda is ondersoek. Organiese bemesting is teen vier peile toegedien (hoendermis: 0, 6.25, 12.5 and 25 kg 10 m^{-2}; kraalmis: 0, 12.5, 25 and 50 kg 10 m^{-2}; kompos: 0, 25, 50 and 100 kg 10 m^{-2}). Elke behandelingskombinasie is vier keer herhaal. Organiese bemestingstowwe is een maand voor plant in die grond ingewerk. Aantal blare en planthoogte is weekliks vir die eerste agt weke na plant vir beide gewasse bepaal. Tydens oes is die nat- en droëmass van beide kool en geelwortels bepaal. Kool se kopdeursnee en geelwortels se skouerdeursnee asook wortellengte en totale oplosbare vastestowwe is gemeet. Beide gewasse is tydens oes volgens hul eksterne voorkoms gegradeer (kool in 3 klasse en geelwortels in 5 klasse). Na oes is grondontledings (2005 en 2006) asook plantontledings (2006) gedoen vir beide gewasse.

Die groei en ontwikkeling van koolplante is tydens die eerste agt weke na plant betekenisvol deur 12.5 en 25 kg 10 m^{-2} hoendermis verhoog in beide seisoene. In 2005 was die varsmassa en kwaliteit van kool wat 12.5 of 25 kg 10 m^{-2} hoendermis ontvang het betekenisvol hoër as die van kool wat ander organiese bemesting toedienings ontvang het. Die varsmassa en kwaliteit van kool wat 50 kg 10 m^{-2} kraalmis, 25 kg 10 m^{-2} hoendermis of 100 kg 10 m^{-2} kompos ontvang het in 2006 was betekenisvol hoër as die ander behandelings en die droëmassa was ook hoër waar 25 kg 10 m^{-2} hoendermis toegedien is. Kompos het die stikstof-, fosfor-, kalium-, swawel- en kalsiuminhoud van die grond betekenisvol verhoog terwyl kraalmis die fosfor, kalsium en magnesiuminhoud betekenisvol na twee jaar verhoog het. Die twee hoogste toedienings peile (Peil 2 en 3) van organiese bemesting het in die meeste gevalle die grootste invloed gehad op die chemiese eienskappe van die grond. Dit was slegs hoendermis wat die stikstofinhoud van koolkoppe betekenisvol beïnvloed het.

Tydens die eerste agt weke na plant het geelwortelplante wat hoender- of kraalmis (Peil 2 of 3) ontvang het, meeste aantal blare gevorm en die hoogste plante is waargeneem waar 25 kg 10 m^{-2} hoendermis of 50 kg 10 m^{-2} kompos toegedien is. Verskillende organiese bemesting en verskillende toedieningspeile het nie die varsmassa of die lengte van die wortels betekenisvol beïnvloed nie. In 2006 was die droëmassa van geelwortels wat 25 kg 10 m^{-2} hoendermis, 50 kg 10 m^{-2} kraalmis of 25 kg 10 m^{-2} kompos ontvang het betekenisvol hoër as die wat geen bemesting ontvang het nie. Die hoogste toedieningspeil van organiese bemesting het die skouerdeursnee van wortels betekenisvol vergroot. Die totale oplosbare vastestowwe in geelwortels is deur hoendermis en kompos betekenisvol verlaag (2005). In 2006 is die hoogste totale oplosbare vastestofinhoud verkry met 12.5 kg 10 m^{-2} hoendermis. In 2005 het hoë toedieningspeile die voorkoms van harige wortels verhoog en die swakste kwaliteit is verkry waar kompos in 2006 toegedien is. Kompos het die fosfor-, kaliuminhoud en die NIRS organiese materiaal inhoud van die grond betekenisvol verhoog. Kraalmis het slegs die swawel inhoud van die grond verhoog. Stikstofinhoud van geelwortels is betekenisvol deur 100 kg 10 m^{-2} kompos of 25 kg 10 m^{-2} hoendermis verhoog. Die kalsiuminhoud van geelwortels is betekenisvol verlaag waar hoendermis toegedien is, terwyl die ysterinhoud betekenisvol deur kraalmis verhoog is en 6.25 kg 10 m^{-2} hoendermis die koolstofinhoud verhoog het.

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TABLE OF CONTENTS

CHAPTER 2
MATERIAL AND METHODS

CHAPTER 3

INFLUENCE OF ORGANIC FERTILISERS ON THE YIELD AND QUALITY OF CABBAGE (*Brassica oleracea* var. *capitata* L.)

CHAPTER 4

INFLUENCE OF ORGANIC FERTILISERS ON THE YIELD AND QUALITY OF CARROTS (*Daucus carota* L.)

CHAPTER 5

NUTRIENT UPTAKE BY CABBAGES (*Brassica oleracea* var. *capitata* L.) AS INFLUENCED BY ORGANIC FERTILISER

CHAPTER 6

SOIL AND CARROT (*Daucus carota* L.) NUTRIENT CONTENTS AS INFLUENCED BY ORGANIC FERTILISER

CHAPTER 7

SUMMARY AND RECOMMENDATIONS

MOTIVATION AND OBJECTIVES

A. MOTIVATION

Agricultural production systems practiced in KwaZulu-Natal range from subsistence farming to large-scale commercial farming. The input cost of fertilisers and chemicals are among the highest and have forced farmers, farming at subsistence level, to develop farming systems that exclude these products. Instead, farmers are using whatever organic sources they have to provide crops with essential elements for growth and development. The problem these farmers are faced with is to know how much organic fertiliser to apply for a specific crop (Oelhaf, 1978; Allemann & Young, 1993; Gontcharenko, 1994).

No clear recommendations exist for organic fertiliser application and since organic sources differ in their nutrient composition as well as the rate of nutrient release, farmers tend to apply either too little or too much organic fertiliser. As a result, soil structure is influenced negatively and the amount of nutrient supplied by the organic material is either insufficient or toxic for plant growth and yield of a good quality. Excessive organic fertiliser application rates contribute to soil pollution in that salts tend to accumulate in the soil and leaching of nutrients from the root profile occurs. High nitrate levels also accumulate in the harvested produce, which is again not good for human health (Oelhaf, 1978; Lampkin, 2000; Vandendries, 2002, Zakaria & Vimala, 2002).

Organic fertilisers improve soil tilth and structure, thereby allowing root development into deeper soil layers. This in turn promotes plant growth and increases yield. Although the use of organic fertilisers is one of the oldest methods in crop production used by farmers, especially where these organic sources are in abundance, it should be remembered that the use of fresh manure is not recommended due to its burning effects on plants, especially young seedlings (Oelhaf, 1978; Taiz & Zeiger, 1991; Lampkin, 2000, FSSA, 2003). Among the essential elements needed by crops, nitrogen is the element that limits growth the most. Nitrogen deficiency is also more likely to occur where immature compost is used since microbes use nitrogen during the breakdown of organic material, which is supposed to be used by the plants (Oelhaf, 1978; Taiz & Zeiger, 1991; Lampkin, 2000, FSSA, 2003).

Organic fertilisers are made from materials derived from plant and animal residues. The positive effect of most commonly used organic fertilisers on crop production and soil fertility are dependent on the quality, rate, timing and method of application. The amount of nutrients and the type of elements available from the specific organic fertiliser used is again dependent on the age, origin as well as climatic conditions such as temperature and rainfall (Grubinger, 1999; Lampkin, 2000; FSSA, 2003).

Cabbage and carrots are produced throughout the year in KwaZulu-Natal. Spring or summer application of organic fertiliser as well as incorporation of it into the soil four weeks before planting resulted in higher yields of good quality than autumn or winter applications of organic fertilisers. The reason for this is that mineralization of organic fertiliser that is faster in summer and spring than in winter and autumn with the result that more nutrients are available for plant growth (Oelhaf, 1978; Allemann & Young, 1993; Grubinger, 1999; Lampkin, 2000).

Many studies were conducted to compare the influence of organic fertilisers versus inorganic fertiliser on the yield and quality of cabbage and carrots. However, most of these studies were using chicken, poultry manure or compost and not kraal manure. These studies also paid more attention to internal quality aspects such as nitrate, vitamin and mineral levels of the crop and concentrated less on external quality aspects such as colour, head and shoulder diameter, root length, forking and hairy skin.

B. OBJECTIVE

The main objective of this study was to investigate the response of vegetables to organic fertiliser.

a. Sub-objectives

- To determine the response of cabbage to different organic fertilisers (Chapter 3)
- To determine the response of carrots to different organic fertilisers (Chapter 4)
- To establish the fertility status of the soil treated with organic fertilisers (Chapter 5 (cabbage) and 6 (carrots))

CHAPTER 1

LITERATURE REVIEW

1.1 GENERAL

Organic fertilisers are all forms of organic soil amendments that originate from both livestock waste and crop residues, with the nutrients in them being mineralised by soil microbes and slowly making them available to plants over a long period of time (Lampkin, 2000; FSSA, 2003). Organic fertilisers contain mineral nutrients in the form of complex organic molecules and the levels of nutrients are much lower than inorganic fertilisers. Organic fertilisers also have a longer residual effect than inorganic fertilisers. Inorganic fertilisers are specially made to provide essential nutrients faster even during unfavourable conditions such as autumn and spring. In other words, inorganic fertilisers do not depend on the activity of microbes to release nutrients. Therefore, inorganic fertilisers are required in smaller amounts and they are easy to store as well as to apply to the soil compared to organic fertilisers. Inorganic fertilisers do not supply humus to the soil, so the nutrient and water holding capacity of the soil may be less than that of organic fertilised soil. This lower capacity as well as high solubility of inorganic fertiliser leads to faster leaching of nutrients (nitrogen) from the soil (Taiz & Zeiger, 1991; Lampkin, 2000; Rembialkowska, 2003). Before using organic fertilisers, farmers need to know the advantages and disadvantages of these organic sources.

This literature review will focus on the advantages and disadvantages, nutrient content and quality of organic fertilisers. Attention will also be given to the factors affecting organic fertiliser efficiency, timing and method of organic fertiliser application. Influence of organic fertilisers on growth, yield and quality of crops will also be addressed including control of pests, diseases and weeds when using organic fertiliser.

1.2 ADVANTAGES AND DISADVANTAGES OF ORGANIC FERTILISERS

1.2.1 Advantages

- By using slow decomposing materials such as compost or leaf mould the chances of over-fertilisation is reduced since the availability of minerals will not influence the plant negatively.
- Organic fertilisers add humus to the soil and this has the ability to hold positively charged ions (cations) and negatively charged ions (anions) and make them available to the plants through the process of exchange capacity**.**
- Humus added by organic fertilisers adsorbs large quantities of water and makes it available to plants during drought. This feature as well as the capacity to hold nutrients is important for sandy soils which retain very few nutrients and water (Scholl & Nieuwenhuis, 2004).
- Humus serves as an effective buffer regulating the balance between acid and base in the soil solution, i.e. soil pH (Veerabhadraiah & Hamegowda, 2006; Naramabuye *et al.*, 2007).
- Organic fertilisers enrich the soil with organic matter, which improves soil structure or workability (soil tilth), making the soil easier to plough (sand and clay soils). Since clay soil has few macro–pores, it inhibits the transport of water and oxygen to plant roots leading to suffocation, plant stress (directly) or susceptibility of plants to diseases and pests (indirectly). Therefore, the application of organic fertilisers assist structuring of clay soil to open and admit air penetration to roots and water drainage, both conditions necessary for satisfactory plant growth (Eimhoit *et al.*, 2005).
- Organic matter enhances root growth and nutrient uptake resulting in higher yields.
- The dark colour of humus absorbs heat, thereafter high specific heat helps to stabilize the soil temperature or warm up the soil especially in spring.
- Through composting methods, diseases, pests and weed seeds are destroyed by high temperature in the compost heap (Scholl & Nieuwenhuis, 2004).

1.2.2 Disadvantages

- Nutrients in organic fertilisers are not immediately available due to slow release by soil micro-organisms.
- Information on the amount of nutrients and the exact elements in an organic fertiliser is not readily available to farmers.
- Organic fertilisers are expensive and bulky especially if they are produced far from the place of production.
- Nutrient deficiencies are difficult to rectify.
- Improper use of organic fertilisers can cause nitrates to accumulate in ground water, and also in crops if they are taken up by the plant roots (Oelhaf, 1978; Gontcharenko, 1994).
- Improper processed organic fertilisers may contain pathogens from plant or animal matter that are harmful to humans or plants.
- Compost derived from municipal waste and sewage may contain toxic elements such as lead, cadmium and arsenic that contaminate food and reduce quality.

1.3 NUTRIENT CONTENT OF ORGANIC FERTILISERS

Organic fertilisers are derived from different raw materials and that is why they vary in their nutrient composition. Generally, cow or kraal manure is lowest and poultry manure highest in nutrients. Fresh poultry manure contains two or three times as much nitrogen than kraal manure or compost. The composition of manure depends very much on the quality of animal feed. The richer the feed in proteins, the richer the manure is in nitrogen. Similarly, the more phosphorus and potassium in the feed, the more of these constituents there are in organic fertiliser (Lampkin, 2000).

Organic fertiliser composition also varies with its age and the extent to which it is exposed to air. When exposed and allowed to dry out, much of the nitrogen in the organic fertiliser may be lost to the air (volatilisation). Potassium may also be lost from the manure through leaching action of rain water. Because of many factors that affect the chemical composition of organic fertilisers, Table 2.1 serves only as a guide (Okalebo & Woomer, 2005).

Table 2.1 Nutrient content of organic fertilisers

Organic fertiliser	Nutrients N	P (%)	K	Reference
Kraal manure	1	0.8	2	Lampkin (2000)
Raw cattle manure	1.1	0.4	1	FSSA (2003)
Composted cattle manure	1.6-2.2	0.6-1.2	1-1.3	FSSA (2003)
Cattle manure (fresh)	25	15	25	Boyhan *et al.* (1999)
Fish meal (dry)	10	4	0	Boyhan *et al.* (1999)
Fish scrap (dry)	3.5-12	1-12	0.8-1.6	Boyhan *et al*. (1999)
Bone meal (steamed)	0.7-4	18-34	0	Boyhan *et al.* (1999)
Chicken manure	3	1	1	Lampkin (2000)
Chicken manure	2.6	2.9	3.4	Zakaria & Vimala (2002)
Chicken manure	2.2-3.5	1.7-2.2	1.5-2.3	FSSA (2003)
Guano	8-16	3.5-4.5	2.0-4.5	FSSA (2003)
Sewer waste (dry)	±3.0	±1.3	±0.4	FSSA (2003)
Sewage sludge (active dry)	2-6	3-7	0-1	Boyhan *et al.* (1999)
Sewage sludge (digested)	1-3	0.5-4	0-0.5	Boyhan *et al.* (1999)
Peat	±1.6	±0.2	±0.1	FSSA (2003)
Worm compost	1.9	1.7	2.0	Zakaria & Vimala (2002)
Poultry manure + sawdust + rice husk compost	0.59	0.23	0.29	Zakaria & Vimala (2002)
Poultry manure + sawdust compost	2.01	1.32	1.79	Zakaria & Vimala (2002)
Mushroom compost	0.4-0.7	57-62	0.5-1.5	Boyhan *et al.* (1999)
Compost (not fortified)	1.5-3.5	0.5-1	1-2	Boyhan *et al.* (1999)
Poultry manure (75% H_20)	1.5	1	5	Boyhan *et al.* (1999)
Poultry manure (50% H_20)	2	2	1	Boyhan *et al.* (1999)
Poultry manure (30% H_20)	3	2.5	1.5	Boyhan *et al.* (1999)
Poultry manure (15% H_20)	6	4	3	Boyhan *et al.* (1999)

As a result of variation in nutrient content among organic fertilisers, farmers tend to apply not enough or more than the demand of the soil–crop system (Auweele & Vandendriessche, 2002). Over fertilisation creates pollution problems such as nitrate leaching especially in poorly drained soils as well as an increase in soil phosphorus content. On the other hand, under fertilisation results in slow growth of vegetables and poor quality yield. Gontcharenko (1994) and Alt & Rimmek (1996) found the application of organic fertiliser at a rate of 15 or 60 t ha^{-1} $year^{-1}$ to be insufficient to supply enough humus for holding nutrients for plant growth. Gutezeit (2001) reported that in high rainfall areas, where soils are acidified and highly leached, deficiencies of boron and zinc can be corrected by applying high levels of chicken manure.

Another problem is that organic fertilisers have a relatively low nutrient content, thus large quantities of organic fertilisers are required to supply enough nutrients for optimum growth of a crop. For vegetables such as cabbages (heavy feeder), organic fertilisers with a low nutrient content reduce growth as well as the crop yield (Lampkin, 2000; Masuda *et al*., 2002).

Interpretation of the results of a soil analysis and calculation of the amount of organic fertiliser to be applied for each crop can be helpful in controlling under- or over-fertilisation. Leaf analysis can also be done and this shows the nutrient status of the plant at a particular time of sampling. Leaf analysis is often done in time for deficiencies to be corrected while the crop is still immature (Grubinger, 1999; Lampkin, 2000; FSSA, 2003).

1.4 QUALITY OF ORGANIC FERTILISERS

Plant roots take up water and nutrients from the soil, and therefore the sufficient supply of both water and nutrients are imperative for optimum crop growth. One way of supplying nutrients is the application of well decomposed manure or compost. If compost is not well decomposed, it will continue with the decomposition process and further tie up nutrients that are present in the soil. During the decomposition process, nitrogen utilised by soil micro-organisms will result in nitrogen deficiency (nitrogen negative period). To minimize losses, organic fertiliser should be heaped and stored for a minimum amount of time (not longer than six weeks) and worked into soil as soon as possible after broadcasting. Since composted materials are more stable and easier to handle, they are highly recommended as a source of nutrients (Taiz & Zeiger, 1991; Lampkin, 2000; FSSA, 2003).

Sometimes organic fertilisers, especially compost made from municipality waste and sewage, are found to have toxic elements such as arsenic, cadmium and lead which are harmful to the growth of the crops as well as to human health. The use of contaminated compost or manure results in the contamination of soil and crops (Gontcharenko, 1994). Maturity of organic fertiliser is an important aspect of quality.

Maturity is determined by the carbon to nitrogen ratio with an ideal C:N ratio of approximately 15:1. If the ratio is more than 15:1 there is a possibility that nitrogen might be immobilised, and in such cases a nitrogen rich source (guano or inorganic nitrogen) should be mixed with the organic fertiliser to improve the quality (Grubinger, 1999; FSSA, 2003; Levy & Taylor, 2003). Furthermore, the pH should be close to neutral while moisture levels should be less than 35%.

1.5 FACTORS AFFECTING THE EFFECTIVENESS OF ORGANIC FERTILISERS

The effectiveness of good quality organic fertiliser can be increased by combining it with other important factors such as availability of water, soil characteristics (type, depth, pH, slope percentage and temperature) and timing of cultural practices (Gupta, 1987).

1.5.1 Soil water

No matter how much manure or compost is applied, if good quality water is not available plant growth would be poor since water plays a role in dissolving nutrients and act as transport thereof. Irrigation water should also be tested before use to determine the electrical conductivity (EC) which is an indication of the salinity level of the water. Accumulation of salts in the water will prevent roots from taking up nutrients from the soil. The electrical conductivity of both the water and the soil for vegetable production should not be more than 2 mmoh cm^{-1} but when vegetables are grown in compost or peat–lite mix the electrical conductivity can be two or three times higher (Hudson *et al*., 1990; Grubinger, 1999).

1.5.2 Soil type

Conditions in the soil should be conducive for mineralisation. Since sandy soil has larger or macro pores it is able to release water (well drained) and allows air to occupy space. As a result of good aeration in sandy soil, micro-organisms are able to breathe and, therefore, the breakdown of organic fertiliser to release nutrients (mineralisation) is fast. In wet soil (clay soil) micro-organisms are unable to get oxygen due to micro-pores which are occupied by water i.e. anaerobic condition and, therefore, mineralisation is poor or slow (Grubinger, 1999).

1.5.3 Soil depth

In soil with an effective rooting depth of less than 300 mm (shallow soils) the application of organic fertilisers is less effective because the growth of roots to deeper layers is restricted**.** Most of the organic matter and nutrients are found in the top layer of the soil, but plant roots can also extract nutrients from the subsoil. If the soils are shallow, the roots have to get all the nutrients and water from the top soil. Therefore soil assessment should be conducted before planting to determine the effective rooting depth (ERD). An effective rooting depth of 30–60 cm is ideal for vegetable production (Allemann & Young, 2002; Scholl & Nieuwenhuis, 2004).

1.5.4 Soil pH

Soil pH is the key to proper plant growth since it can affect it directly or indirectly. Too acid or too alkaline soils create an unfavorable balance between acid and alkaline elements needed by the plants and it has a toxic effect on plants. Indirectly, soil acidity inhibits the availability of essential elements and reduces the activities of micro-organisms.

A pH ranging between 5.5 and 7.0 is best for growth of most plants (Hudson *et al*., 1990). Organic fertilisers react differently towards increasing or decreasing the soil pH. Layer manure has the ability to decrease soil pH and increase the acid saturation of the soil while the application of compost increases soil pH (Rubeiz *et al*., 1993; Wong *et al*., 1998). In high rainfall areas soils are acidified and if this is not treated accordingly, they reduce the response of plants to applied fertiliser. Gontcharenko (1994) reported on the negative effect of soil acidity on the roots of tomatoes and cabbage. Soil acidity promoted root rot disease which again reduced the yield of tomatoes and cabbage. Thus, soil samples should be analysed before planting to determine the soil pH and if necessary, incorporate lime (Grubinger, 1999).

1.5.5 Slope

Land with a slope of more than 18% is unsuitable for vegetable production since soil erosion is high and applied manure or compost is washed away to streams or rivers (Grubinger, 1999).

1.5.6 Soil temperature

Soil temperature plays a very important role in the decomposition of organic fertiliser and the uptake of nutrients by plants. For optimum decomposition of organic materials by soil micro-organisms, the temperature should be above 60ºC. At this temperature weeds and harmful pathogens can be killed. If the temperature is below 60ºC during composting, compost may still contain weed seed or harmful pathogens. Soil temperature can increase to a level that is not conducive for plant growth especially when soil is exposed directly to the sun during the day. By applying organic fertiliser as a mulch, the radiation is blocked and the temperature during day time isreduced. This situation is conducive for seed germination, plant growth (root) as well as the growth of micro-organisms. Crops like cabbage and carrots can be grown throughout the year in KwaZulu Natal but perform better in cooler months. The application of organic fertiliser will be better during the more favourable months (Oelhaf, 1978; Grubinger, 1999; Lampkin, 2000; McLaurin, 2000; Scholl & Nieuwenhuis, 2004).

1.6 TIMING OF ORGANIC FERTILISER APPLICATION

Timing of organic fertiliser application is very important since it affects the availability of plant nutrients. In warmer areas the maintenance of the humus level in soil is difficult to achieve since the breakdown of humus is faster and carbon returns to the atmosphere (Liu & Li, 2003). Organic fertilizers should be analysed first before planting to determine the amount of essential nutrients as well as toxic elements present. The application of nutrients should not exceed the soil–crop demand as this may promote salinity or pollution problems. In order to minimize leaching of nitrate and optimize its use, manure should be applied in spring (Lampkin, 2000). For the production of crops such as cabbage, potatoes and tomatoes, organic fertilisers need to be incorporated into the soil; while for root crops such as carrots and beetroot organic fertilisers need to be applied to the previous crop. Fresh manure that contains excessive amounts of nitrogen and salts should not be used because it could burn the roots of the crop and decrease the level of crop resistance to pests.

1.7 METHOD OF ORGANIC FERTILISER APPLICATION

Approximately 75% of the nitrogen in manure is derived from urine and if there is no bedding in the kraal, most of the urine is lost through seepage into the soil. If manure remains exposed to sunlight, wind or rain after it has been broadcasted on top of the soil, nitrogen may be lost. To prevent this, organic fertilisers must be incorporated into the soil one month before planting in order to combine well with soil particles and also to reduce the burning effect if it is not well decomposed (Grubinger, 1999; Lampkin, 2000). Before spreading organic fertiliser, the soil need to be loosened to a depth of 30 cm, thereafter the soil should be moistened to prevent organic fertiliser from drying. A layer of organic fertiliser, about 10 cm thick, should then be spread evenly on the surface. This should be worked in, to a depth of 25 cm near the root zone, so that the roots can have an immediate source of nutrients. The second layer of organic fertiliser, about 10 cm thick, needs to be spread and left on the surface as a mulch in order to improve the structure of the soil and to retain moisture.

1.8 INFLUENCE OF ORGANIC FERTILISERS ON GROWTH, YIELD AND QUALITY OF CROPS

1.8.1 Growth

Since the nutrient content and the rate of nutrient release vary among organic fertilisers, the level of growth is either positively or negatively affected. In comparing the growth of vegetables that received inorganic fertiliser with that of plants that received organic fertiliser, researchers reported that the early growth was slower. This could be attributed to the lower levels of nutrients especially nitrogen and phosphorus in organic fertilisers available for plant growth. With the help from soil microbes (indicated by biomass carbon and biomass nitrogen) organic fertiliser releases various nutrients which are then converted from unavailable forms to available forms for plant growth. In addition, microbes produce plant growth regulators important for plant growth and photosynthetic activity. That is why vegetables will grow better at a later growth stage and result in higher yields which can be attributed to high nutrient sustainability of organic fertiliser and improved biological properties of the soil (Levy & Taylor, 2003; Xu *et al.,* 2003; Walker & Bernal, 2004).

The emergence of tomato, cucumber, pepper, radish and cress seedlings treated with compost from municipality solid waste and pulp mill solids took longer and the percentage emergence was also lower than the seedlings that received peat-lite mix. At the end, the growth of seedlings that received compost was equal or more vigorous than the seedlings that received peat-lite mix. This is a clear indication that compost releases nutrients very slowly (Roe *et al*., 1997; Levy & Taylor 2003).

In nutrient depleted soil (sandy) and soil with high percentage of clay, the application of organic fertilisers such as beet molasses, mink farm compost, horse manure compost, agricultural waste, yard waste compost and poultry manure was found to improve the soil structure and stimulated the growth of corn, carrots and cabbage roots to a depth of 150, 10 and 35 cm, respectively. As the roots grow without any interruption to deeper soil layers, they are able to extract nutrients and this will promote the growth rate (plant height, number of leaves) of crops (Levy & Taylor, 2003; Hu & Barker, 2004; Walker & Bernal, 2004). As the number of leaves increase, more light is intercepted and photosynthesis rate enhanced, resulting in high dry matter production. This influence of organic fertilisers is also influenced by crop type and time of application. Liu & Li (2003) studied the effect of organic and inorganic nutrient solutions on growth and quality of a vegetable (*Brassica campestris*) in a soilless culture with an application of 50 t ha^{-1} manure. The fresh mass of plants treated with an organic solution was 25.52% higher than those plants treated with an inorganic solution in winter, but in spring, there was no difference because all climatic factors were favourable.

1.8.2 Yield

Yield of any crop depends on the quality of organic fertiliser and the correct placement. There are mixed results on the yield of crops. Differences in yields between organic and inorganic fertilisers are small and do not always favour organic or inorganic farming systems. The decline in yields of organic treated plants may be due to lower fertiliser application rates and/ or slower nutrient release i.e. mineralisation as well as nutrient uptake (Warman, 2000).

Since leaves are the main organ of photosynthesis, any reduction in leaf number results in lower yields, but some plants benefit from leaf reduction in winter because the transpiration rate is reduced. Organic fertilisers that contain high amounts of nutrients were found to produce high yields. Many studies have compared the yields of organically fertilised plants with that of inorganic fertilised plants. The organic fertilised (cattle manure, barnyard manure, beet vinasse, farm yard manure compost, chicken manure and processed chicken manure) crops (beetroot, radish, carrots, cabbage, potatoes, sweetcorn, lettuce and amaranthus) yielded (fresh mass) more than the inorganic fertilised (Lopez *et al.*, 1993; Nader *et al*., 1993; Warman & Havard, 1996 a & b; Zdravkovic *et al.*, 1997; Zakaria & Vimala, 2002; Rembialkowska, 2003). Similarly to the above, other studies have reported an increase in the dry mass of celeriac, beetroot, carrots, onions, cabbage, potatoes, beetroot and tomatoes, respectively, with the application of various types of organic fertilisers (Leclerc *et al.*, 1991; Nader *et al.,* 1993; Rembialkowska, 2003; Suojala, 2003; Hu & Barker, 2004).

Organic produced vegetables do not always yield higher than inorganic treated vegetables. Since organic fertilisers differ in their nutrient content, the application of organic fertilisers that are deficient in some essential elements like potassium and nitrogen contribute to slow growth and lower yields as compared to plants treated with inorganic fertilisers. The yield of cucumber, tomatoes, cabbage and potatoes treated with inorganic fertiliser was higher than that of the organic fertilised crops (Gontcharenko, 1994; Haraldsen *et al*., 2000).

The difference in nutrient content of organic fertilisers has an influence on yield produced. The high nutrient content (nitrogen) of composted dairy manure and cattle manure has contributed to a higher yield (fresh & dry mass) of carrots, onions and cabbage than that of vegetables treated with poultry manure or alkaline stabilised composted dairy manure (Blatt, 1991; Suojala, 2003). However, the combination of organic fertiliser (green manure, palm oil mill effluent) and inorganic fertiliser (N, P and K) produced yields of cucumber and cabbage that were higher than those of plants treated with green manure or palm oil mill effluent alone (Zakaria & Vimala, 2002).

1.8.3 Quality

The quality of vegetables cannot be defined in terms of any single, measurable characteristic. In fact, it is usually assessed by three critical criteria namely technological suitability (specific attributes which determine suitability for processing and storage), nutritional value (content of beneficial nutrients, such as protein, vitamins and content of harmful substances such as nitrates, natural toxins, pesticide residues and heavy metals) and appearance (size, shape, colour, freedom from blemishes and a taste specifically associated with individual products). In many cases, these quality characteristics can be measured quantitatively and thus provide a basis for comparison (Allemann & Young, 2002).

1.8.3.1 Internal quality

Nutritional value

Regarding nutritional quality, more concerns are oriented towards negative aspects such as pesticide residues, food additives, fats and to a lesser extent nitrates than towards positive factors such as protein, vitamins and trace elements. Organic produced vegetables have shown a decrease in the concentration of undesirable compounds such as Cd, Zn, Cu, NO_3^-, Pb and an increase in the concentration of desirable compounds such as vitamin A, B_1 (thiamin), B_2, B_{12} (cynocobalamin), C, E, β-carotene, soluble protein, carbohydrates, total sugars (sucrose, glucose and fructose) and mineral compounds (Ca, K, Mg, S and Na) compared to inorganic produced vegetables (Leclerc *et al.,* 1991; Nader *et al*., 1993; Mozafar, 1994; Warman & Havard, 1996 a & b; Wong *et al*., 1998; Premuzic *et al.*, 2002; Liu & Li, 2003; Rembialkowska, 2003; Suojala, 2003; Xu *et al.*, 2003).

Nader *et al.* (1993) and Rubeiz *et al.* (1993) reported that organic produced carrots and cabbage contained a high concentration of Cd and NO_3^- as well as a low level of β-carotene. It is well known that a high nitrate level is undesirable for human health because it is converted to nitrites which combine with hemoglobin and inhibits oxygen transport. Thus, to produce good quality vegetables it is important to grow them during the optimum time (spring) since nitrates accumulate in vegetables during cold climates (Liu & Li, 2003).

1.8.3.2 External quality

External appearance is the most obvious quality aspect that organic produced food sometimes fails to show when compared with inorganic produced food.

Taste

It is widely accepted that organic produced food tastes better than inorganic produced food because it contains naturally occurring plant based compounds (phyto–nutrients), which are able to give the plants their distinctive colour and flavour. Coleman (1993) conducted a taste study using a panel of 30–50 consumers who were not informed about the basis of comparison; the result showed that organic produced vegetables were of better taste than inorganic produced vegetables. This was attributed to high concentrations of vitamins, and sugars in organic grown vegetables.

Size

The structural superiority of an organic soil enhances textural quality of root and stem crops by maintaining uniform soil moisture and nutrient levels. This situation allows carrots to expand their roots to deeper layers without any interruption. At harvest it is possible to obtain carrots with a root length of 15 cm and shoulder diameters ranging from 1.9–2.5 or 3 cm while potatoes produce tubers with a minimum diameter of 4–9 cm. Other crops such as cabbage, broccoli, cauliflower and lettuce have shown to produce heads of good quality with diameters of 14.9; 13.9; 17.9 and 10.9 cm respectively (Blatt, 1991; Warman & Havard 1996 a & b; Stone, 1998).

Colour

Carrots produce several colours with orange or orange red colours being the most popular. The colours produced are dependent on the cultivars planted. Although cultivars differ in their potential for orange colour, soil fertility, temperature and water content are the three main factors affecting root colour. Timing of organic fertiliser application (spring) and proper irrigation management in sandy or loamy soils plays an important role for good colour development (Fritz, 2007). For example, temperatures above 20ºC and below 15ºC (KwaZulu Natal) reduce the colour of carrots. Since organic only produced vegetables are rich in vitamins, the yellow, orange color of carrots, sweet potatoes, apricots and pumpkins is caused by a vitamin precursor carotene, i.e. β–carotene which is a member of the family of nutrients known as carotenoids. β–carotene is also the primary source of dietary provitamin A, which is converted by our bodies to vitamin A. β–carotene also acts as an antioxidant to protect against certain types of cancer. Vitamin A is also essential for good vision, a strong immunity and reproductive health (Leclerc *et al.,* 1991*).*

Forking

Although organic fertiliser is taken as the sole promoter of forking and hairy roots in carrots, the review of previous studies showed that forking was the result of many factors such as poor soil structure (compacted soil) and heavy applications of fresh manure. Application of high nitrogen fertiliser rates in sandy soil with low moisture levels also increases forked roots, and visa versa (Gutezeit, 2001; Fritz, 2007).

Storage life

The application of organic fertiliser increases the firmness of cabbage heads as well as the shelf life of the produce. In a study conducted by Coleman (1993), lower storage losses were obtained in organic treated crops such as carrots, beetroot kohlrabi, potatoes and cabbage than inorganic treated vegetables. Similarly, Rembialkowska (2003) also reported a 22% mass loss in organic fertilised potatoes as compared to 30% of inorganic fertilised potatoes during storage.

1.9 PEST AND DISEASE CONTROL

In the tropics, weeds grow rapidly and provide hiding places for pests. On the other hand, high temperatures, humidity and sunshine throughout the year offer an environment which is conducive for pest and disease development, but in winter the pest and disease population is very low. The use of organic fertilisers allows the direct uptake by plants of specific chemicals such as phenols, which are needed for the development of the plant's immune system and also results in plants being protected from diseases (Zakaria & Vimala, 2002). Application of organic fertiliser increases the total number of beneficial anthropods that helps to control harmful pests such as *Hymenoptera*, rove beetles (*Drusilla leach*) and aphids (Berry, 1996). The type and quantity of organic fertiliser also has an influence on the appearance of pests and diseases. Sheep–composted manure was shown to produce the highest population of flea beetles compared to fresh manure, while organic fertilisers containing high nitrogen levels increases aphid populations as well as fungal diseases in organic grown beans (Lampkin, 2000).

To produce good quality organic food, subsistance farmers need to control flea beetles, aphids and diseases using herbicides or pesticides that are environmentally friendly such as wood vinegar and beta-sprays, tea tree oil and herbal preparations, garlic and neem although these sometimes are not effective in reducing pest populations. Other methods of controlling aphids include prevention of water stress or splashing or washing aphids on leaves with water (Lampkin, 2000). However, previous studies have shown that by intercropping Indian mustard (grown as hedgerows) with cabbage, pests were reduced (Zakaria & Vimala, 2002).

1.10 WEED CONTROL

Weeds compete with crops for sunlight, nutrients, water and space and, therefore, at harvest lower yields are obtained. Using organic fertiliser as a mulch (depending on its thickness) helped to smother and reduce weeds in carrots and red beet, aphids in cabbage fields and also shaded the soil thus preventing it from drying out. Mulch that consists of a layer of dry grass, leaves, maize stover or coarse compost spread evenly over the surface conserved moisture, while run-off and erosion was also prevented (Peacock, 1991; Lampkin, 2000; Borowy, 2004).

Raw manures may be contaminated with weed seed, either seed that has passed undigested through animals or from bedding materials. The application of this manures or slurry to the field may increase weed problems. Therefore, to reduce the number of viable weed seed, manures should be composted at temperatures higher than 60ºC (hot composting) and the temperature should be maintained at that level for three days.

1.11 CONCLUSIONS

According to literature, there are a number of advantages but also disadvantages in using organic fertilisers. It is also evident that it is possible to produce quality vegetables when using organic fertilisers. To achieve quality vegetables with a high yield, it is important that other factors such as pH, water, type, depth, slope and temperature of the soil is at an optimum for organic fertiliser to be effective. Timing, method of application and quality of the organic fertiliser used, will determine the success rate. Organic fertilisers used need to be fully decomposed, free from insects, pathogens, weed seed and other pollutants that can reduce the yield and quality of vegetables.

CHAPTER 2

MATERIAL AND METHODS

2.1 GENERAL

To achieve the objectives of this study, field trials were conducted during 2005 and 2006 at the Msunduze Training Centre in the Ndwedwe district of KwaZulu-Natal. The area falls under the bio-resource group (BRG 1) consisting of moist coastal forest with thorn and palm veld. This area is 165-677 m above sea level with an average annual rainfall of 878 mm and an average day temperature of 19.4ºC. All soil, organic fertiliser and plant analysis were done at the laboratories of the Department of Agriculture and Environmental Affairs (Soil Fertility and Analytical Service Section) of the KwaZulu-Natal Government at Cedara.

2.2 SOIL CHARACTERISTICS

2.2.1 Soil sampling and analysis

Field trails were done on the same soil in both the 2005 and 2006 season. Before planting, soil samples were collected at a depth of 15 cm (topsoil) following a zig–zag pattern across the entire field. The collected samples (40) were thoroughly mixed and analysed. Some of the physical and chemical properties of the soil are indicated in Table 2.1.

The soil is classified as a well drained Inanda form (Soil Classification Working Group, 1991) with an effective root depth of more than 80 cm, a clay percentage of 48% and a slope of 5%. The fertility status of the soil was in general not acceptable for vegetable production. The low soil $pH_{(KCl)}$ of 4.5 was associated with a high acid saturation (21%). A $pH_{(KCl)}$ of 6–6.5 and an acid saturation of 1% is regarded as optimum for both cabbage and carrot production (Smith, 1998; Allemann & Young, 2001).

Table 2.1 Physical and chemical properties of the soil used for cabbage and carrot trials at the start of the 2005 season

Property*	
$pH_{(KCl)}$	4.5
%	
Clay	48
Acid saturation	21
Organic carbon	2.2
Total cations (cmol L^{-1})	4.74
mg L^{-1}	
P (Ambic 2)	8
K (Ambic 2)	99
Ca (KCl)	363
Mg (KCl)	202
Zn (Ambic 2)	22
Cu (Ambic 2)	1.6
Mn (Ambic 2)	4

*Determined with the batch-handling procedure which is similar to rapid procedure used for soil analysis (Hunter, 1975; Farina, 1981)

2.3 MANURE AND COMPOST CHARACTERISTICS

Chicken and kraal manure as well as compost were bought from National Plant Food CC trading as Gromor at Cato Ridge, KwaZulu-Natal. The same batch of manure and compost were used in both seasons and, therefore, the analysis was only done once and the results are presented in Table 2.2.

Table 2.2 General properties of organic fertilisers (chicken, kraal manure and compost) analysed

Property*	Organic fertiliser		
	Chicken manure	Kraal manure	Compost
pH$_{(KCl)}$	6.71	7.19	7.56
		(%)	
Total organic carbon	37.74	24.97	19.79
Moisture content	24.41	34.87	21.11
N (NH_4OA_c)	3.16	2.10	1.35
P (Ambic 2)	1.47	0.96	0.76
K (Ambic 2)	2.68	2.17	1.15
S (NH_4OA_c)	0.62	0.48	0.41
		mg L^{-1}	
Na (NH_4OA_c)	4791.5	3540.3	2479.3
Ca (KCl)	3.31	2.74	3.84
Mg (KCl)	0.69	0.65	0.46
Cu (Ambic 2)	87.2	55	45.7
Mn (Ambic 2)	711	772	694
Zn (Ambic 2)	607	225	247
Al (HCl)	2358	8003	9327
Fe (HCl)	3346	29032	26095

***Determined with the batch-handling procedure which is similar to rapid procedure used for soil analysis (Hunter, 1975; Farina, 1981)**

2.4 EXPERIMENTAL DESIGN AND TREATMENTS

2.4.1 Trial layout

In 2005 two field trials were laid out as a complete randomized block design with four replications, one for cabbage (cv. Conquistador) and one for carrots (cv. Kuroda). This was repeated in 2006 on exactly the same site and the same treatments were allocated to the same plots as was the case in 2005. Each trial consisted of 48 treatment combinations. Plot dimensions were 3 x 2.5 m for cabbage and 2 x 1 m for carrots, with a buffer zone of 0.5 m between all plots.

2.4.2 Treatments

2.4.2.1 Organic fertilisers

Three different organic fertilisers were used in these field trials, namely chicken manure, kraal manure and compost.

2.4.2.2 Application rates of organic fertilisers

Organic fertilisers were applied at different rates: chicken manure at 0, 6.25, 12.5 and 25 kg 10 m^{-2}; kraal manure at 0, 12.5, 25 and 50 kg 10 m^{-2} and compost at 0, 25, 50 and 100 kg 10 m^{-2}. These levels were selected according to the recommendations of Allemann & Young (1993) and Wong *et al*. (1998). Because of space limitations only one inorganic fertiliser treatment, as recommended for commercial cabbage and carrot production, was added as a reference at a rate of 1.5 kg 2:3:4(30) 10 m^{-2}.

2.5 PRODUCTION ASPECTS

2.5.1 Soil preparation

Dolomitic lime (300 kg lime 624 m^{-2}) was incorporated to a depth of 25 cm four weeks before planting in order to raise the soil pH to between 6 and 6.5 and also to decrease the soil acid saturation from 21% to the permissible 1%. Before spreading organic fertilisers on the soil surface, the soil was moistened to prevent organic fertilisers from drying. All (100%) the organic fertilisers were spread and worked into the soil four weeks before planting to a depth of 25 cm in order to allow the roots of the plants to have an immediate source of nutrients at the root zone.

2.5.2 Cabbage seedling production

2.5.2.1 Seedbed preparation

The soil was loosened with a garden fork up to a depth of 20 cm and raked to break up any clods in preparation of a fine and even surface. Seedbeds were raised to 15 cm above the natural soil surface to facilitate drainage and accommodate access pathways (0.5 m) between plots. Cabbage seeds were sown in shallow furrows drawn 15 cm apart and covered with soil to a depth of 2 cm.

2.5.2.2 Caring for the seedlings

Water was applied by means of a watering can. After sowing, frequent (daily or even twice daily during hot dry weather) light irrigations was necessary to prevent the top soil, in which the seed was sown, from drying out. After emergence, the intervals between irrigations were increased to 7 days as the seedlings became stronger. Watering over the last 7-10 days before transplanting was reduced to harden the seedlings. The beds were soaked two days before transplanting in order to restore a good water regime for the seedlings, and to facilitate lifting of the seedlings with minimal root damage.

2.5.2.3 Transplanting

The cabbage seedlings were transplanted 45 days after sowing in both 2005 and 2006. Only short sturdy, slightly hardened cabbage seedlings of about 10-15 cm tall and with 4-5 true leaves were transplanted in the plots with a spacing of 50 cm between plants in the row and 60 cm between rows.

2.5.3 Sowing of carrots

2.5.3.1 Sowing seed

Carrot seeds were sown directly at a depth of 1.5 cm with a spacing of 20 cm between rows in both 2005 and 2006.

2.5.3.2 Thinning

Thinning was done 20 days after emergence to a final spacing of 5 cm between plants in the row.

2.5.4 Irrigation

A watering can was used to irrigate cabbage plants two to three times a week (40-60 mm H_2O plot^{-1}) for the first 3-4 weeks after transplanting and thereafter once a week (20 mm H_20 plot^{-1}) until harvesting. Carrot plants were irrigated once or twice a day (20-40 mm H_20 plot^{-1}) for 60 days and thereafter once a week.

2.5.5 Weeding

Weeds (black jack – *Bidens* spp. and tall khaki weed – *Tagetes minuta*) were controlled twice during the growth season manually by pulling out the weeds or by using a hand hoe.

2.5.6 Insect and disease control

Insects (aphids and American bollworm) and leaf spot disease on cabbage were controlled three times using a mixture of soapy water and grinded chilies. The insect repellant was prepared by grinding 500 g of green chilies and grating 250 g of sunlight soap. This was then soaked in 1 L of H_20 for 24 hours. Thereafter, 9 L of H_20 was added to the mixture and the solution was sieved to remove any solids. The solution was sprayed onto plants using a knapsack sprayer (Smith & McGrath, 2000).

2.5.7 Harvesting

Only the cabbage and carrot plants located in the centre of the plots were harvested. Fifteen cabbage heads and 180 carrots per plot were harvested. Cabbage was harvested 105 days after transplanting in 2005 and 90 days after transplanting in 2006. Carrots were harvested 105 and 90 days after planting in 2005 and 2006, respectively.

2.6 DATA COLLECTION

The same parameters were collected in 2005 and 2006, except where mentioned otherwise.

2.6.1 Growth parameters

2.6.1.1 Plant height

Plant height of cabbage and carrots was measured with a ruler every two weeks. Plant height was measured from the highest leaf down to the collar of both cabbage and carrots. This was done from planting up to 8 weeks after transplanting.

2.6.1.2 Number of leaves

The number of fully developed leaves of cabbage and carrots were counted every two weeks from planting up to 8 weeks after transplanting.

2.6.1.3 Insect and disease infestation (scouting)

The level of insect and disease infestation was determined once a week by walking on a transect (scouting) across four plots and stopping at a total of 4 places, spaced and representing a transect across the entire field in both 2005 and 2006 seasons. Scouting for grey cabbage aphids (*Brevicoryne brassicae*), American bollworm (*Helicoverpa armigera)* and Alternaria leaf spot disease (*Cercospora brassicicola* or *Alternaria brassicae*) was identified.

2.6.2 Yield components

2.6.2.1 Fresh mass

During harvest, the fresh mass of cabbage heads and carrots without leaves were determined by weighing.

2.6.2.2 Dry mass

A sample of three cabbages and ten carrots (only the roots) per plot was selected randomly during harvesting, placed in clean paper bags and sent to the laboratory where the samples were dried for 48 hours at 75°C and the dry mass was determined.

2.6.3 Quality components

2.6.3.1 Head or shoulder diameter

At harvest, the head diameter of cabbage was measured at the widest part of the head and the shoulder diameter of carrots was measured 2 cm from the top of the shoulder using a ruler.

2.6.3.2 Root length

Root length of carrots was determined at harvest by means of a ruler starting from the shoulder to the end of the root tip.

2.6.3.3 Grading

Cabbage: Cabbage was graded into three classes, i.e. Class 1 (good quality) was cabbage with a round shape, fresh green leaves and no insect damage; Class 2 (poor quality but suitable for consumption) was cabbage with a round shape and minor insect damage and Class 3 (poor quality unsuitable for consumption) was allocated to cabbages with severe insect damage and pale leaves.

Carrots: At harvest, carrot roots were graded into five classes according to the level of smoothness, shape (forking) and colour. Carrots with a deep orange colour, very smooth skin and conical in shape were graded under Class 1 (very smooth); Class 2 were carrots with a deep orange colour, smooth skin and conical in shape; Class 3 were carrots with deep orange colour, average hairs and conical in shape; Class 4 were slightly forked carrot roots with a deep orange colour and hairy (unsmooth) skin while forked carrot roots with more hairs and deep orange in colour were graded under Class 5 (poor quality).

2.6.3.4 Total soluble solids (TSS)

A sample of ten carrots per plot was send to the laboratory for TSS analysis using the enzymatic-colometric procedure described by Marais *et al.* (1966).

2.6.4 Plant analysis

Cabbage: A sample of three cabbages plot^{-1} selected randomly were harvested and sent to the laboratory where the samples were dried at 75°C, then grinded to pass through a 0.84 mm sieve. Cabbage heads were only analysed in 2006.
Carrots: A sample of ten carrots (roots) plot^{-1} were harvested, placed in clean paper bags, labeled and sent to the laboratory for analysis. The samples were dried at 75°C then grinded to pass through a 0.84 mm sieve. Roots of carrots were analysed only in 2006.

For both cabbage and carrots the phosphorus concentration was determined by Ambic 2 extract, while potassium, sodium, calcium, magnesium, copper, manganese and zinc were determined by atomic absorption. Samples for boron analysis were ashed separately and boron determined photometrically by the azomethine H method (Gaines & Mitchell, 1979).

2.6.5 Soil analysis

After harvesting cabbage and carrots, two soil samples per cabbage plot and one soil sample per carrot plot were taken to a depth of 15 cm (topsoil) using a soil sampler or auger. The sampling difference was based on the size of the plot since each cabbage plot was 7.5 m^2 while that of carrots was 2 m^2. The samples were thoroughly mixed and dispatched for analysis. Samples were dried at 75°C then grinded to pass through a 0.84 mm sieve to determine the nutrients status of the soil. The rapid procedure method described by Hunter (1975) and Farina (1981) were used for analysis.

2.7 STATISTICAL ANALYSIS

As mentioned already, all field trials were laid out in a complete randomized block design. Analysis of variance was done on every measured parameter to determine the significance of differences between means of treatments using the NCSS 2000 program (Hintze, 1999). Means for each parameter were separated by the least significant difference (LSD_{Tukey}) test at $P \leq 0.05$.

CHAPTER 3

INFLUENCE OF ORGANIC FERTILISERS ON THE YIELD AND QUALITY OF CABBAGE (*Brassica oleracea* var. *capitata* L.)

3.1 INTRODUCTION

Cabbage is one of the most important leafy vegetable produced by subsistence farmers for food security as well as to generate income. It is an excellent source of vitamins A, C, K, B_1, B_2, B_6, calcium, dietary fiber and protein when it is eaten raw (salad), shredded, boiled or cooked as stew or soup (Atkins, 1999; Mateljan, 2007). The prerequisite for cabbage production is a fertile soil that will provide all the nutrients necessary to promote growth. No matter what fertiliser source is used by farmers, it has to supply all essential nutrients required by cabbage (El-Shinawy *et al.*, 1999).

Organic fertilisers such as compost, chicken and kraal manure used for vegetable production supply nitrogen, potassium and phosphorus to plants which are necessary for growth. Since cabbage has a high nutritional requirement, farmers fail to meet its nutrient requirements due to the fact that organic fertilisers from different sources vary considerably in nutrient level and composition. Readily available organic fertilisers are applied at rates in excess for most crops. Such rates lead to an increase in soil salinity, which may result in lower crop yields (Rubeiz *et al.*, 1998).

For organic fertilisers to be efficient, they need to be combined with other factors such as availability of water, soil type, temperature and cultural practices. These factors affect the efficiency of mineralisation and subsequently the utilisation of nutrients by the growing crop. For example, the availability of adequate soil moisture is a factor that is critical when determining the amount of nutrients that are mineralised and absorbed by the plant. Soil applied organic fertiliser assists in maintaining soil moisture regimes which are considered to be favourable for plant growth (Gupta, 1987). The application of organic fertiliser also increases the populations of micro-organisms in the soil that helps the soil to release various nutrients. These micro-organisms also produce plant growth regulators that are important for plant growth and photosynthetic activity (Levy & Taylor, 2003; Walker & Bernal, 2004).

Although plant growth is defined as an increase in plant size, it is not the only measure of growth. Growth can also be determined by measuring the number of leaves, the main photosynthetic plant organ. Leaf area index (LAI) is a way of measuring the capacity of a crop to produce dry matter. Variation in LAI of a plant can result from changes in leaf number or size. As LAI increases, the loss of lower leaves increases due to shading. Insufficient nutrient supply by organic fertilisers causes the LAI to increase very slowly after germination thereafter it is followed by a period of rapid expansion. As the LAI increases, light absorption and the rate of dry matter production increases (Xu *et al.*, 2003).

Cabbage absorbs nitrogen released by organic fertilisers in the form of ammonium (NH_4^+), which is less effective in promoting growth than nitrate (NO_3^-). Thus for such a high value crop like cabbage, proper nutrition is important in order to produce a high yield but also of good quality. There is a correlation between the amount of nitrogen applied and the quality of cabbage. Cabbage heads will not form if there is a nitrogen shortage. On the other hand, excess nitrogen may cause the formation of loose heads with internal decay. The demand for phosphorus is greater during head formation and a shortage will result in purple leaves. Potassium deficiency can also result in necrosis and reduce head quality but an excess of potassium can cause cracked heads (El-Shinawy *et al.*, 1999).

The benefit of obtaining high yields after organic fertiliser application was more evident in sandy soil than in loam soil (Rubeiz *et al.*, 1993; Rubeiz, *et al*., 1998). At harvest, yield was measured as fresh mass but fresh mass is sometimes considered as a poor indicator of growth due to fluctuation caused by changes in the water status of a plant. For this reason, dry mass is a more accurate measurement (Taiz & Zeiger, 1991). According to several researchers, cabbage yield (fresh and dry mass) where organic fertiliser was used compared well to the yield of inorganic fertilised cabbage. For quality components of cabbage, head diameter and fresh mass are measured and then heads graded according to size, colour, shape and firmness.

Organically grown cabbage produces firmer heads with a better quality compared to inorganically grown cabbage (Premuzic *et al.*, 2002; Suojala, 2003; Xu *et al.*, 2003).

Cabbage can be grown at any time of the year but better quality and greater yields can be obtained during warmer months of the year. In summer soil temperatures are high and the break down of organic fertiliser is faster than in winter which again increases its efficiency. High temperature causes nutrients, especially nitrogen, to be available to the growing plants much quicker and will result in high quality yields (Blatt, 1991). The objective of this study was, therefore, to evaluate the effect of organic fertilisers on yield and quality of cabbage.

3.2 RESULTS AND DISCUSSION

3.2.1 Growth parameters

3.2.1.1 Leaf number

The summary of analysis of variance determining the effect of different organic fertilisers and application rates on the number of cabbage leaves during the first 8 weeks after transplanting shows that the interaction between organic fertiliser and application rate was not significant in both 2005 and 2006 (Table 3.1).

Different organic fertilisers and also application rates did not significantly influence the number of cabbage leaves in 2005. It was only at week 8 after transplanting that organic fertiliser application rates significantly influenced the number of cabbage leaves. In 2006 the number of cabbage leaves was significantly influenced by the different organic fertiliser application rates over all sampling times. Different organic fertilisers significantly influenced the number of cabbage leaves only at 2 weeks after transplanting in 2006.

Table 3.1 Summary of the analysis of variance showing the significant effects of organic fertiliser and application rate on the number of cabbage leaves during the first eight weeks after transplanting in 2005 and 2006

Weeks after transplanting	Organic fertiliser (OF)	Organic fertiliser application rate (OFR)	OF X OFR
		2005	
2	ns	ns	ns
4	ns	ns	ns
6	ns	ns	ns
8	ns	*	ns
		2006	
2	*	*	ns
4	ns	*	ns
6	ns	*	ns
8	ns	*	ns

LSD ($T \leq 0.05$)
ns = no significant differences
***= significant differences**

2005 Season

The highest organic fertiliser application rate (Rate 3) produced plants with significantly more leaves than plants that did not receive any fertiliser (Rate 0) (Table 3.2). Although not significant, plants that received low organic fertiliser rates (Rates 1 or 2) also formed more leaves than plants that did not receive any fertiliser.

Table 3.2 Influence of organic fertiliser application rate on number of cabbage leaves at 8 weeks after transplanting in 2005

Organic fertiliser application rate (OFR)	Number of leaves
0	14.33
1	15.83
2	15.83
3	16.50
$LSD_{(T \leq 0.05)}$ OFR	**2.03**

2006 Season

At 2 weeks after transplanting, cabbage plants treated with chicken or kraal manure had significantly more leaves than plants treated with compost (Table 3.3). Cabbage plants that received inorganic fertiliser, which was added as a reference for commercial cabbage production, produced less leaves over the first two weeks after transplanting than plants that received organic fertiliser. This, however, was not analysed statistically because of space restriction as was mentioned in the Chapter 2 (Section 2.4.2.2).

Table 3.3 Influence of organic fertiliser on number of cabbage leaves at 2 weeks after transplanting in 2006

Fertiliser (OF)	Number of leaves
Chicken manure	8.13
Kraal manure	8.13
Compost	7.69
LSD$_{(T\leq 0.05)}$ OF	**0.44**
2:3:4(30)	7.30

From the growth data (Table 3.3) it seems that compost releases nutrients slower than chicken and kraal manure. Compost is derived from various organic materials such as plant and animal residues that need to be broken down by microorganisms before it can release nutrients and therefore it is known to release nutrients slower than other organic fertiliser sources (Starbuck, 2001; Rosen & Bierman, 2005). Jakse & Mihelie (1999) reported that the growth rate of spinach and cabbage was slower where chicken manure or bark was applied compared to where inorganic fertiliser was applied. For tomatoes the growth rate was also slower where composted municipal solid waste or pulp mill solids were applied compared to mink farm compost or composted horse manure and this was related to nitrogen immobilisation in compost (Levy & Taylor, 2003).

The number of cabbage leaves increased as organic fertiliser rates increased at weeks 2, 6 and 8 after transplanting, although this was not always significant (Table 3.4). Two weeks after transplanting, the highest organic fertiliser rate produced plants with significantly more leaves than plants that did not receive any fertiliser and plants that received a low organic fertiliser rate (Rate 1). During week 4 after transplanting, both Rates 1 and 3 produced plants with significantly more leaves than plants that did not receive any fertiliser. Later in the growing season (6 and 8 weeks after transplanting) all plants that received organic fertiliser, irrespective of the rate, produced significantly more leaves than plants that did not receive any fertiliser.

Table 3.4 Influence of organic fertiliser application rate on number of cabbage leaves during the first 8 weeks after transplanting in 2006

Organic fertiliser application rate (OFR)	Weeks after transplanting			
	2	4	6	8
0	7.58	10.75	13.83	15.58
1	7.75	12.00	15.42	17.17
2	8.08	11.83	16.17	17.42
3	8.50	11.92	16.42	18.25
$LSD_{(T\leq 0.05)}$ OFR	**0.56**	**1.14**	**1.37**	**1.26**

Different types of organic fertilisers did not influence the number of leaves during the first 8 weeks after transplanting in 2005. It was only in the second year where chicken and kraal manure significantly influenced the number of leaves at 2 weeks after transplanting. The reason for this may be build up of the organic matter in the soil during the first year. However, from literature it is also evident that compost is a slower releaser of nutrients (Starbuck, 2001; Rosen & Bierman, 2005) than manure. During 2005, only the highest organic fertiliser rate (Rate 3 at 8 weeks after transplanting) significantly influenced the number of cabbage leaves. As the rate of the different organic fertilisers increased, the number of cabbage leaves also increased over the first 8 weeks after transplanting in 2006, although not always significant. At 6 and 8 weeks after transplanting all plants that received organic fertiliser had significantly more leaves than plants that did not receive any fertiliser.

Cabbage plants treated with chicken or kraal manure formed the most number of leaves compared to plants treated with compost in the early growth period of 2006. This may be attributed to the differences in the nutrient content of the organic fertilisers used especially the phosphorus content which is important for root growth. Other researchers also reported on the role of different types of organic fertiliser on emergence and early growth of crops. Tomato, cucumber and pepper seedlings treated with compost took longer to emerge and the percentage emergence was also lower than seedlings that received peat–lite mix (Roe *et al.*, 1997). Walker & Bernal (2004) reported that early vegetative growth of *B. oleracea* and *B. carinata* was significantly greater when poultry manure was used as fertiliser. Tomato plants formed significantly more leaves when Mink farm compost, horse manure compost, agricultural waste compost or yard waste was used as fertiliser compared to plants treated with municipal solid waste compost or pulp mill solids (Levy & Taylor, 2003; Hu & Barker, 2004).

3.2.1.2 Plant height

A summary of the analysis of variance determining the effect of different organic fertilisers and application rates on plant height of cabbage during the first 8 weeks after transplanting shows that the interaction between organic fertiliser and application rate was only significant in 2006 (Table 3.5).

Table 3.5 Summary of the analysis of variance showing the significant effects of organic fertiliser and application rate on plant height of cabbage during the first 8 weeks after transplanting in 2005 and 2006

Weeks after transplanting	Organic fertiliser (OF)	Organic fertiliser application rate (OFR)	OF X OFR
		2005	
2	ns	*	ns
4	ns	*	ns
6	ns	*	ns
8	ns	*	ns
		2006	
2	*	*	*
4	*	*	*
6	ns	*	*
8	ns	*	*

LSD $_{(T \leq 0.05)}$
ns = no significant differences
*** = significant differences**

Different organic fertilisers did not significantly influence plant height of cabbage during the first 8 weeks after transplanting in 2005, but in 2006 it was significantly influenced during the first 4 weeks after transplanting. Organic fertiliser application rates significantly influenced plant height during the first 8 weeks after transplanting in both 2005 and 2006.

2005 Season

Organic fertiliser Rates 2 and 3 resulted in plants that were significantly taller than plants that received no organic fertiliser from 4 up to 8 weeks after transplanting (Table 3.6). At 8 weeks after transplanting, cabbage plant height increased from

8.79 cm where no fertiliser was applied to 11.33 and 10.46 cm where organic fertiliser was applied at Rates 2 and 3 respectively. This same trend was observed during week 4 and 6 after transplanting. From week 4 after transplanting the height of cabbage plants tended to decrease when the rate of organic fertilisers increased from 2 to 3 but this was, however, not significant.

Table 3.6 Influence of organic fertiliser application rate on plant height (cm) of cabbage during the first 8 weeks after transplanting in 2005

Organic fertiliser application rate (OFR)	Weeks after transplanting			
	2	4	6	8
0	4.83	6.75	7.71	8.79
1	4.33	6.75	8.38	9.54
2	5.08	8.58	10.08	11.33
3	5.67	7.83	9.29	10.46
$LSD_{(T \leq 0.05)}$ OFR	**1.04**	**1.06**	**1.48**	**1.57**

2006 Season

Plant height of cabbage was positively influenced by organic fertiliser rate irrespective of the organic fertiliser type (Table 3.7). Chicken manure applied at 12.5 or 25 kg 10 m^{-2} significantly increased the height of cabbage plants compared to plants that did not receive any fertiliser over all four sampling times. Plants that received 25 or 50 kg 10 m^{-2} kraal manure were also significantly taller than plants that did not receive any fertiliser at weeks 2 and 8 after transplanting. At 4 and 6 weeks after transplanting, 12.5 kg 10 m^{-2} kraal manure also significantly influenced cabbage plant height. Cabbage plants that received 25, 50 or 100 kg 10 m^{-2} compost were significantly taller than plants that did not receive any fertiliser at 4, 6 and 8 weeks after transplanting. Plants that received inorganic fertiliser were taller than plants that received organic fertilisers at weeks 4, 6 and 8 after transplanting (Table 3.7).

At 8 weeks after transplanting, plants that received compost were the tallest (9.88 cm) followed by chicken manure (9.65 cm) and then kraal manure (9.25 cm), although these differences were not significant. Plant height tended to decrease when the organic fertiliser increased from Rate 2 to 3 at week 8 after transplanting for all the different organic fertiliser types and this was also observed in 2005.

Table 3.7 Influence of organic fertiliser and application rate on plant height (cm) of cabbage in 2006

Fertiliser (OF)	Fertiliser application rate (kg 10 m^{-2})	Weeks after transplanting			
		2	4	6	8
Chicken manure	**0**	3.00	4.00	5.88	6.88
	6.25	3.00	4.13	6.15	6.88
	12.5	3.70	6.70	8.20	9.65
	25	4.23	6.13	6.80	9.25
Kraal manure	**0**	3.00	3.50	5.53	6.93
	12.5	3.25	5.63	6.30	7.25
	25	4.52	6.75	8.25	9.25
	50	4.60	6.88	8.75	9.13
Compost	**0**	3.00	3.50	5.50	6.63
	25	3.10	5.50	7.52	8.80
	50	3.70	5.75	7.88	9.88
	100	4.70	5.88	7.88	8.25
LSD$_{(T\leq0.05)}$ OF x OFR		**0.66**	**0.63**	**0.67**	**0.77**
2:3:4(30)	**1.5**	4.38	7.80	10.20	11.00

Application rate of organic fertilisers significantly influenced the growth of cabbage (if plant height is used as an index). Plants that received organic fertiliser at Rate 2 or 3 were significantly taller than plants that received organic fertiliser at Rate 1 or where no fertiliser was applied in 2005. In 2006, plants treated with 50 kg 10 m^{-2} kraal manure were the tallest at 6 weeks after transplanting. At 8 weeks after transplanting cabbage plants treated with 50 kg 10 m^{-2} compost were the tallest. Several researchers obtained similar positive results with organic fertiliser on growth of different crops such as *B. oleracea*, *B. carinata*, cucumber, tomatoes and peppers (Levy & Taylor, 2003; Hu & Barker, 2004; Walker & Bernal, 2004).

Cabbage plants treated with inorganic fertiliser tended to be taller than plants that received organic fertiliser. El-Shinawy *et al.* (1999) also reported that lettuce plants treated with inorganic fertiliser were taller than plants treated with buffalo manure.

3.2.2 Yield components

In order to establish the yield of cabbage, fresh and dry mass were measured. A summary of the analysis of variance determining the effect of different organic fertilisers and application rates on fresh and dry mass of cabbage indicates that both parameters reacted the same. The interaction between organic fertiliser and application rate was significant in 2006 for both the fresh and dry mass of cabbage (Table 3.8). Organic fertiliser and organic fertiliser rate significantly influenced the fresh and dry mass of cabbage in 2005 and 2006.

Table 3.8 Summary of the analysis of variance showing the significant effects of organic fertiliser and application rate on fresh and dry mass of cabbage in 2005 and 2006

Yield	Organic fertiliser (OF)	Organic fertiliser application rate (OFR)	OF X OFR
	2005		
Fresh mass	*	*	ns
Dry mass	*	*	ns
	2006		
Fresh mass	*	*	*
Dry mass	*	*	*

LSD $_{(T\leq 0.05)}$
ns = no significant differences
***= significant differences**

3.2.2.1 Fresh mass

2005 Season

As shown in Table 3.9 the fresh mass of cabbage treated with compost (875 g) or kraal manure (894 g) was significantly lower than that of cabbage treated with chicken manure (1413 g). Interestingly, the fresh mass of cabbage that received inorganic fertiliser weighed less (1290 g) than cabbage that received chicken manure but more than those treated with kraal manure or compost, although not statistically so.

Table 3.9 Influence of organic fertiliser on fresh mass of cabbage in 2005

Fertiliser (OF)	Fresh mass (g)
Chicken manure	1413
Kraal manure	894
Compost	875
$LSD_{(T\leq 0.05)}$ OF	**404**
2:3:4(30)	1290

As the organic fertiliser rate increased, fresh mass of cabbage also increased. Cabbage fresh mass significantly increased from 125 g where no fertiliser was applied to 1608 g and 1567 g where organic fertiliser was applied at Rates 2 and 3, respectively (Table 3.10). Plants that received organic fertiliser produced significantly heavier heads than plants that did not receive any organic fertiliser (Rate 0). When organic fertiliser rate increased from 2 to 3, fresh mass tended to decrease, although this was not significant.

Table 3.10 Influence of organic fertiliser application rate on fresh mass of cabbage in 2005

Organic fertiliser application rate (OFR)	Fresh mass (g)
0	125
1	942
2	1608
3	1567
$LSD_{(T\leq 0.05)}$ OFR	**515**

2006 Season

In this season, the fresh mass of cabbage also increased with an increase in the rate of organic fertiliser irrespective of the source. Fresh mass of cabbage that received chicken manure (12.5 or 25 kg 10 m^{-2}) was significantly greater than all the other organic fertiliser treatments. Where chicken manure was applied, the fresh mass of cabbage was significantly greater (2060 and 2700 g) where kraal manure (1150 and 1600 g) or compost (1200 and 1630 g) were applied at the two highest rates. Cabbage that received inorganic fertiliser also weighed less than cabbage that received 12.5 or 25 kg 10 m^{-2} chicken manure (Table 3.11). No decrease in fresh mass was observed when the organic fertiliser increased from Rates 2 to 3, which was observed in 2005.

Table 3.11 Influence of organic fertiliser and application rate on the fresh mass of cabbage in 2006

Fertiliser (OF)	**Fertiliser application rate (kg 10 m^{-2})**	**Fresh mass (g)**
Chicken manure	**0**	500
	6.25	900
	12.5	2060
	25	2700
Kraal manure	**0**	0
	12.5	525
	25	1200
	50	1630
Compost	**0**	700
	25	800
	50	1150
	100	1600
LSD$_{(T\leq0.05)}$ OF x OFR		**149**
2:3:4(30)	**1.5**	1867

In both 2005 and 2006 different organic fertilisers and different application rates significantly influenced cabbage fresh mass. The best results were obtained with 12.5 or 25 kg 10 m^{-2} chicken manure in both seasons. The two highest organic fertiliser rates irrespective of the organic fertiliser source influenced the fresh mass of cabbage positively. Rubeiz *et al*. (1993) also reported an increase in the fresh mass of cabbage treated with broiler and layer manure. Fresh mass of lettuce was also influenced possitively by chicken manure (Rubeiz *et al*., 1998; El-Shinawy *et al*., 1999). Other researchers also reported on the positive role of organic fertilisers compared to inorganic fertilisers on the fresh mass of crops such as amaranthus (Zakaria & Vimala 2002); *B. chinensis* (Wong, 1990); peppers and cucumbers (Roe *et al.*, 1997).

3.2.2.2 Dry mass

Dry mass of cabbage responded the same as fresh mass to organic fertiliser application in both seasons. However, the dry mass of cabbage that received inorganic fertiliser in 2005 was greater than that of cabbage that received organic fertiliser, although it was not analysed statistically (Chapter 2, Section 2.4.2.2).

2005 Season

As shown in Table 3.12 the dry mass of cabbage treated with compost (90 g) or kraal manure (91 g) was significantly lower than that treated with chicken manure (150 g). Interestingly, and although not significant, the dry mass of cabbage treated with inorganic fertiliser (164 g) was greater than that treated with chicken manure (150 g).

Table 3.12 Influence of organic fertiliser on dry mass of cabbage in 2005

Organic fertiliser (OF)	Dry mass (g)
Chicken manure	150
Kraal manure	91
Compost	90
$LSD_{(T \leq 0.05)}$ OF	**44**
2:3:4(30)	164

Dry mass of cabbage increased significantly with an increase in organic fertiliser rate (Table 3.13). Although not significant, the dry mass of cabbage decreased from 178 to 147 g when the organic fertiliser increased from Rates 2 to 3. This was also true for the fresh mass of cabbage in 2005.

Table 3.13 Influence of organic fertiliser application rate on dry mass of cabbage in 2005

Organic fertiliser application rate (OFR)	Dry mass (g)
0	17
1	100
2	178
3	147
$LSD_{(T \leq 0.05)}$ OFR	**56**

2006 Season

Chicken manure applied at 25 kg 10 m^{-2} resulted in cabbage with dry mass significantly greater than all the other organic fertiliser treatments (Table 3.14). Although not analysed statistically the dry mass of these cabbages were also greater than that of inorganic fertilised cabbage.

Table 3.14 Influence of organic fertiliser and application rate on the dry mass of cabbage in 2006

Fertiliser (OF)	Fertiliser application rates (kg 10 m^{-2})	Dry mass (g)
Chicken manure	**0**	45
	6.25	76
	12.5	178
	25	227
Kraal manure	**0**	0
	12.5	48
	25	108
	50	147
Compost	**0**	58
	25	75
	50	106
	100	155
$LSD_{(T\leq 0.05)}$OF X OFR		**29**
2:3:4(30)	**1.5**	220

This was, however, different from results obtained in the 2005 season. When chicken or kraal manure was applied the dry mass of cabbage was significantly greater than where no fertiliser was applied. With compost it was only at the two highest rates (50 and 100 kg 10 m^{-2}) where the dry mass was significantly more than where no fertiliser was applied. A decrease in the dry mass was also not observed when organic fertiliser increased from Rates 2 to 3 as was observed in 2005.

In both seasons, the different organic fertilisers and application rates significantly influenced the dry mass of cabbage. The best response for cabbage dry mass was obtained with 25 kg 10 m^{-2} chicken manure. Various other researchers also reported on the positive response of dry mass to organic fertiliser for other crops such as celeriac (Leclerc *et al*., 1991), beetroot (Nader *et al.*, 1993); *B. chinensis*; *Zea mays* (Wong *et al*., 1998), lettuce (Rubeiz *et al.*, 1998) and spinach (Jakse & Mihelie, 1999). Contrary to this, Jakse & Mihelie (1999) found a decrease in the dry mass of cabbage when chicken layer manure and/or bark was applied as fertiliser.
Application of organic fertilisers at different rates significantly increased the yield of cabbage when fresh and dry mass were used as indexes. Chicken manure applied at 25 kg 10 m^{-2} increased the fresh and dry mass of cabbage the most. The nutrients from chicken manure might be more available to the crop compared to kraal manure and compost. This was confirmed by Boyhan *et al.* (1999) when he rated the availability of nutrients among different organic fertilisers as: poultry manure (medium-rapid); cattle or kraal manure (medium) and compost (slow). Zakaria & Vimala (2002) also reported higher yields with chicken manure than with inorganic fertiliser for lettuce and tomatoes. Comparing the fresh mass and dry mass of cabbage between 2005 and 2006, no differences could be found to support the build-up of organic matter in the soil over time.

3.2.3 Quality components

To establish quality, cabbage was graded into three classes according to size, external appearance, shape and firmness (explained earlier in Chapter 2) and thereafter head diameter was measured. A summary of the analysis of variance to determine the effect of different organic fertilisers and application rates on the grading and diameter of cabbage heads in 2005 and 2006 is given in Table 3.15.

Table 3.15 Summary of the analysis of variance showing the significant effects of organic fertiliser and application rate on grading and head diameter of cabbage in 2005 and 2006

Quality	Organic fertiliser (OF)	Organic fertiliser application rate (OFR)	OF X OFR
		2005	
Grading	ns	*	ns
Head diameter	ns	*	ns
		2006	
Grading	*	*	*
Head diameter	*	*	*

LSD $_{(T \leq 0.05)}$
ns = no significant differences
***= significant differences**

As shown in Table 3.15, the interaction between organic fertiliser and application rate was only significant in 2006 for both grading and head diameter. The different organic fertiliser application rates significantly influenced grading and head diameter of cabbage in 2005 and 2006. Different organic fertilisers significantly influenced grading and head diameter of cabbage only in 2006.

3.2.3.1 Grading

2005 Season

The two highest organic fertiliser rates (Rates 2 and 3) produced cabbage that was significantly of a better quality than those that received a lower rate (Rate 1) organic fertiliser and those that did not receive any fertiliser (Table 3.16). Cabbage that received no fertiliser was graded as poor quality (Class 1) compared to organic treated cabbage that was graded as Classes 2 and 3.

Table 3.16 Influence of different organic fertiliser application rates on grading of cabbage in 2005

Organic fertiliser application rate (OFR)	Class
0	3
1	2
2	1
3	1
$LSD_{(T \leq 0.05)}$ OFR	**0.4**

Class: 1 = good quality
2 = poor quality but suitable for consumption
3 = poor quality (unsuitable for consumption)

2006 Season

The quality of cabbages decreased as the rate of organic fertiliser decreased (Table 3.17). Cabbage treated with 6.25, 12.5 or 25 kg 10 m^{-2} chicken manure produced cabbages that graded significantly better than those that did not received any fertiliser.

Table 3.17 Influence of different organic fertilisers and application rates on grading of cabbage heads in 2006

Fertiliser (OF)	Organic fertiliser application rate (kg 10 m^{-2})	Class
Chicken manure	**0**	2
	6.25	1
	12.5	1
	25.0	1
Kraal manure	**0**	2
	12.5	2
	25.0	1
	50.0	1
Compost	**0**	3
	25.0	2
	50.0	1
	100	1
$LSD_{(T \leq 0.05)}$ OF X OFR		**0.6**
2:3:4(30)	**1.5**	1

Class: 1 = good quality
2 = poor quality but suitable for consumption
3 = poor quality (unsuitable for consumption)

Application Rates 2 and 3 of both kraal manure and compost resulted in cabbage that was of significantly better quality than those that did not received any fertiliser (Classes 2 and 3). The quality of cabbages that received organic fertiliser (at the two highest rates) compared well with those cabbages that received inorganic fertiliser.

3.2.3.2 Head diameter

2005 Season

In this season, head diameter of cabbage that received organic fertiliser at different rates was significantly larger than those cabbages that did not receive any fertiliser (Table 3.18). Head diameter increased from 1.5 cm where no fertiliser was applied to 9.67, 11.17 and 12.25 cm at Rates 1, 2 and 3 of organic fertiliser, respectively.

Table 3.18 Influence of different organic fertiliser application rates on head diameter of cabbage in 2005

Organic fertiliser application rate (OFR)	Head diameter (cm)
0	1.5
1	9.7
2	11.7
3	12.3
$LSD_{(T \leq 0.05)}$ OFR	**2.6**

2006 Season

As shown in Table 3.19 organic fertiliser had a positive effect on cabbage head diameter. Plants treated with 25 kg 10 m^{-2} chicken manure produced significantly larger heads (20 cm) than all the other treatments. Head diameter of cabbage plants that received inorganic fertiliser (20.5 cm) compared well to plants that received 25 kg 10 m^{-2} chicken manure (20.0 cm). The two highest chicken (12.5 or 25 kg 10 m^{-2}) and kraal manure (25 or 50 kg 10 m^{-2}) rates significantly increased the diameter of the heads whereas all three compost rates (25, 50 or 100 kg 10 m^{-2}) increased head diameter when compared to cabbage that did not received any fertiliser.

Table 3.19 Influence of different organic fertiliser and application rate on head diameter of cabbage in 2006

Fertiliser (OFR)	Fertiliser application rate (kg 10 m^{-2})	Head diameter (cm)
Chicken manure	**0**	7.9
	6.25	8.5
	12.5	17.1
	25.0	20.0
Kraal manure	**0**	8.5
	12.5	8.7
	25.0	13.9
	50.0	16.7
Compost	**0**	3.0
	25.0	7.8
	50.0	15.0
	100	16.5
$LSD_{(T \leq 0.05)}$ OF X OFR		**0.76**
2:3:4(30)	**1.5**	20.5

Organic fertiliser had a positive influence on cabbage quality when grading and head diameter were used as indexes. Blatt (1991), El-Shinawy *et al.* (1999) and Premuzic *et al*. (2002) also reported on the positive effects of organic fertiliser on the quality of cabbage and lettuce.

In the first season (2005), there was no difference concerning grading of cabbage between the different organic fertiliser sources but as the rate of the organic fertilisers increased, so did the quality. It was only in the second season (2006), where all the plants that received chicken manure graded as Class 1. Cabbages that received kraal manure or compost also graded as Class 1 at the two highest application rates (Rates 2 or 3). Cabbage that received high organic fertiliser rates (Rates 2 and 3) graded the same as those cabbages that received inorganic fertiliser.

The difference between cabbages that received organic and those that received inorganic fertiliser was more evident for head diameter than for grading. Cabbage heads were smaller where compost and kraal manure were applied than where inorganic fertiliser was applied. In 2005 only organic fertiliser rate significantly influenced the head diameter of cabbage. The largest cabbage heads were obtained at Rate 3 although Rate 1 and 2 also significantly influenced head diameter. Application of organic fertilisers as well as different application rates significantly influenced head diameter of cabbage in 2006. The head diameter of cabbage treated with 25 kg chicken manure 10 m^{-2} was significantly larger than all the other treatments. Other researchers also recommended chicken manure for cabbage production due to its high nitrogen content (Rubeiz *et al*., 1993; Rubeiz *et al*., 1998; Zakaria & Vimala, 2002).

In this study there was also no difference in head diameter between plants that received inorganic fertiliser and those that received 25 kg 10 m^{-2} chicken manure. Blatt (1991) also repotted that the head diameter of cabbage, broccoli and cauliflower treated with dry fish silage were comparable to that of cabbage treated with inorganic fertiliser.

3.3 CONCLUSIONS

The source of organic fertiliser did not affect early growth of cabbage (number of leaves and plant height) as much as it influenced yield components (fresh and dry mass) and quality components (grading and head diameter). As was expected, the rate of organic fertiliser applied significantly influenced almost all the parameters measured. It was, however only plant height that tended to decrease when organic fertiliser increased from Rates 2 to 3.

The yield of cabbage was significantly greater where chicken manure was applied and it was even greater compared to plants that received inorganic fertiliser. Cabbage yield also reacted positively to kraal manure and compost, but to a lesser extend than chicken manure. Organic fertiliser applied even at high rates (Rate 3) did not negatively influence the quality of cabbage. Even cabbage that received chicken manure resulted in the largest heads and graded as Class 1 even under high organic fertiliser application rates. Kraal manure and compost also positively influenced the quality of cabbage compared to those that did not receive any fertiliser.

From these results, it is clear that organic fertiliser application influenced cabbage production positively and high application rates did not influence the yield and quality negatively.

CHAPTER 4

INFLUENCE OF ORGANIC FERTILISERS ON THE YIELD AND QUALITY OF CARROTS (*Daucus carota* L.)

4.1 INTRODUCTION

Carrots are one of the vegetables produced by subsistence farmers in KwaZulu-Natal because they are easy to grow and do not need an excess amount of fertilisers (Allemann & Young, 2002). Carrots are also a good source of vitamin A (carotene) B_1, B_2 and C (Leclerc *et al*., 1991; Warman & Harvard, 1996 a & b). Although carrots are medium feeders, they require a fertile soil, which allows rapid uninterrupted growth. Subsistence farmers in this area use organic fertilisers such as chicken manure, kraal manure or compost to provide nutrients to vegetable crops.

From a physiological standpoint, the yield of carrots depends on the production and translocation of carbohydrates from the leaves to the roots. The yield of carrots depends on the cultivar selected, cultural practices applied and the prevailing environmental conditions during the growth of the crop. Leaf number and the plant height of carrots are clear indicators of plant growth. Nitrogen and phosphorus increases root growth, improves the root to shoot ratio and increases dry matter production (Oelhaf, 1978; Taiz & Zeiger, 1991; Grubinger, 1999). Soil moisture also affects the yield and quality of carrots and carrots are most sensitive to moisture stress during root enlargement. The application of potassium fertiliser increases the sugar content of carrots, while moisture stress causes small, woody and poorly flavoured carrots. Forking in carrots is promoted by factors such as poor soil structure (compacted heavy clay soil), application of fresh manure, application of excess nitrogen and improper irrigation management especially in sandy soil. High soil water levels and nitrogen fertilisation decrease forked roots on both sand and loam soils (Gutezeit, 2001; Fritz, 2007). Thus, with an uninterrupted growth the final yield of carrots obtained will be high and of a good quality. However, where there is an interruption in growth the yield will be low and of a poor quality (Blatt, 1991).

Organic fertiliser is normally not recommended for carrot production because of the influence thereof on the quality of carrots. Organic fertilisers promote excessive leaf growth and forked roots that tend to be rougher and coarser on the outside

(Gutezeit, 2001; Allemann & Young, 2002). Zdravkovic *et al.* (1997) and Rembialkowska (2003) obtained greater yields with organic fertilised carrots than with inorganic fertilised carrots. The benefits obtained by using organic fertilisers can, therefore, not be overlooked. Organic fertilisers promote plant growth by supplying the necessary macro nutrients and the influence of organic fertilisers on early crop growth can be explained in two ways (Boyhan *et al*., 1999):

- The uptake of nutrients occurs through the roots by means of diffusion and mass flow. Root growth is, therefore, affected by the placement and quantity of nitrogen and phosphorus. Where the quantity of organic fertiliser is low and the placement incorrect i.e. broadcast, early growth is not promoted (stunted growth). Where the quantity of organic fertiliser is high and the placement is correct i.e. incorporated (next to the root zone) early growth is promoted.

- Since the level of nutrient release is different amongst different organic fertilisers e.g. medium to rapid (chicken manure); medium (kraal manure) and low (compost), the rate of early growth promoted by these sources is quite different.

Timing of organic fertiliser application is important since microorganisms are more active during warmer months than winter. Besides low soil temperature, soil pH also has a negative influence on the uptake of organic nutrients. Low soil temperature (<15°C) causes microorganisms to be inactive. When soil temperature increases to 20ºC, organic materials are broken down and become available for plants. If the soil pH is too low or too high, nutrients also become unavailable to plants (Oelhaf, 1978; Grubinger, 1999; Lampkin, 2000; Allemann & Young, 2002). The application of organic fertilisers to soil with a high percentage of clay reduces the clay percentage and allow carrot roots to penetrate to a depth of 35-110 cm without any interruption. In sandy soil, it improves the soil structure (Kristensen & Kristensen, 2002) and apart from this it also allows the shoulder of carrots to expand with ease. Therefore, at harvest it is possible to find carrots with a minimum shoulder diameter that ranges from 1.9-2.5 cm while the minimum root length ranges from 14.5-24 cm, but this also depends on the cultivar planted and the length of the growing season (Leclerc *et al*., 1991; Warman & Harvard, 1996b; Zdravkovic *et al*., 1997).

Different coloured carrot cultivars are available but the orange or orange red ones are the most desirable. Although cultivars differ in their orange colour, soil fertility, temperature and water are the main factors that influence the colour of carrots. Temperatures above 20°C and below 15°C reduce the colour of carrots. Spring and summer carrots are often of better colour than autumn and winter produced carrots. Carrots grown on sandy soils and soils high in organic matter produce a deeper colour than ones on silt loam soil. Excessive soil water also decreases the colour of carrots (Zdravkovic *et al*., 1997; Fritz, 2007). The aim of the study was to investigate the response of growth, yield and quality of carrots to different organic fertilisers applied at different rates.

4.2 RESULTS AND DISCUSSION

4.2.1 Growth parameters

4.2.1.1 Leaf number

A summary of the analysis of variance to determining the effect of different organic fertilisers and application rates on the number of carrot leaves during the first 8 weeks after thinning showed that the interaction between treatments was not significant in both 2005 and 2006 (Table 4.1).

Table 4.1 Summary of the analysis of variance showing the significant effects of organic fertiliser and rates on the number of carrot leaves during the first 8 weeks after thinning in 2005 and 2006

Weeks after thinning	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF X OFR
	2005		
2	*	*	ns
4	*	*	ns
6	*	*	ns
8	*	*	ns
	2006		
2	*	*	ns
4	*	*	ns
6	*	*	ns
8	ns	*	ns

LSD $_{(T \leq 0.05)}$
ns = no significant differences
*** = significant differences**

Different organic fertilisers and application rates significantly influenced the number of leaves during the first 8 weeks after thinning in 2005 and 2006 except at 8 weeks after thinning for the organic fertiliser in 2006.

2005 Season

Plants treated with chicken manure had significantly more leaves than plants treated with compost over all four sampling times (Table 4.2). No significant differences were found for the number of leaves between plants that received kraal manure and those that received chicken manure. Leaf number for carrot plants that received chicken and kraal manure was 5.31 and 5.25, respectively, compared to 4.88 for plants that received compost (8 weeks after thinning). Plants that received inorganic fertiliser, which was added as a reference for commercial carrot production, produced more leaves over the first 8 weeks after thinning than plants that received organic fertiliser. This was however not analysed statistically because of space restrictions described in Chapter 2, Section 2.4.2.2.

Table 4.2 Influence of organic fertiliser on number of carrot leaves during the first 8 weeks after thinning in 2005

Fertiliser (OF)	**Weeks after thinning**			
	2	**4**	**6**	**8**
Chicken manure	2.31	3.31	4.31	5.31
Kraal manure	2.25	3.25	4.25	5.25
Compost	1.88	2.88	3.88	4.88
LSD($_{T\leq0.05}$) OF	**0.38**	**0.38**	**0.38**	**0.38**
2:3:4(30)	3.00	4.25	5.00	6.00

As shown in Table 4.3 the two highest fertiliser application rates (Rates 2 or 3) produced carrot plants with significantly more leaves compared to those plants that received no fertiliser (Rate 0) or organic fertiliser at a low rate (Rate 1). During week 2 after thinning, the number of leaves increased from 1.33 for plants that received no fertiliser to 2.92 and 2.67 for plants that received organic fertiliser at Rates 2 and 3, respectively. This was true for all four sampling times. Organic fertiliser increased the number of leaves only up to Rate 2, and thereafter number of leaves decreased (Rate 3).

Table 4.3 Influence of organic fertiliser application rate on number of carrot leaves during the first 8 weeks after thinning in 2005

Fertiliser application rate (OFR)	Weeks after thinning			
	2	4	6	8
0	1.33	2.33	3.33	4.33
1	1.67	2.67	3.67	4.67
2	2.92	3.92	4.92	5.92
3	2.67	3.67	4.67	5.67
LSD$_{(T \leq 0.05)}$ OFR	**0.48**	**0.48**	**0.48**	**0.48**

2006 Season

In this season carrot plants showed the same reaction to organic fertiliser as in 2005. Carrot plants that were treated with chicken manure had significantly more leaves than plants treated with compost (Table 4.4) over all the sampling times. Plants that received compost formed 5.00 leaves compared to 5.87 for plants that received chicken manure at six weeks after thinning. There were no significant differences in the number of leaves of carrot plants that received kraal manure and those that received chicken manure. Although not significant, plants that received kraal manure produced more leaves than plants that received compost during the first six weeks after thinning. Carrot plants treated with inorganic fertiliser produced more leaves compared to plants that received organic fertiliser over the first eight weeks after thinning although this was used just as a reference and was not analysed statistically (Chapter 2, Section 2.4.2.2).

Table 4.4 Influence of organic fertiliser on number of carrot leaves during the first 8 weeks after thinning in 2006

Fertiliser (OF)	Weeks after thinning			
	2	4	6	8
Chicken manure	2.56	4.00	5.87	6.81
Kraal manure	2.38	3.56	5.25	6.25
Compost	2.00	3.31	5.00	6.25
LSD$_{(T \leq 0.05)}$ OF	**0.39**	**0.55**	**0.65**	**ns**
2:3:4(30)	3.00	4.27	6.00	6.75

Two weeks after thinning, carrot plants that received organic fertiliser (Rates 1, 2 or 3) produced significantly more leaves than plants that did not received any fertiliser

(Table 4.5). Plants that received the two highest organic fertiliser rates (Rates 2 or 3) formed significantly more leaves than plants that received no fertiliser or a low organic fertiliser rate (Rate1) (four weeks after thinning). At weeks six and eight after thinning, it was only carrot plants that received the highest organic fertiliser rate (Rate 3) that formed significantly more leaves than plants that received no fertiliser. The number of leaves increased from 4.92 and 6.08 (Rate 0) to 5.83 and 7.00 (Rate 3) at six and eight weeks after thinning, respectively.

Table 4.5 Influence of organic fertiliser rate on number of carrot leaves during the first 8 weeks after thinning in 2006

Fertiliser application rate (OFR)	Weeks after thinning			
	2	4	6	8
0	1.58	3.17	4.92	6.08
1	2.17	3.42	5.42	6.50
2	2.83	3.83	5.33	6.17
3	2.67	4.08	5.83	7.00
$LSD_{(T\leq 0.05)}$ OFR	**0.49**	**0.68**	**0.83**	**0.74**

Application of different organic fertilisers at different rates increased the number of carrot leaves during the first eight weeks after thinning in both 2005 and 2006. Carrot plants that received chicken and kraal manure at the two highest rates (Rates 2 or 3) produced the most leaves. Overall, plants that received inorganic fertiliser produced the highest number of leaves in both 2005 and 2006. Hu & Barker (2004) reported an increase in the number of tomato leaves after adding different types of compost such as agricultural waste, sewage sludge and yard waste.

4.2.1.2 Plant height

A summary of the analysis of variance determining the effects of different organic fertilisers and different rates on plant height of carrots during the first 8 weeks after thinning showed that the interaction between organic fertiliser and application rate was only significant in 2006 (Table 4.6).

Table 4.6 Summary of the analysis of variance showing the significant effects of organic fertiliser and application rates on plant height of carrots in 2005 and 2006

Weeks after thinning	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF X OFR
		2005	
2	*	*	ns
4	*	*	ns
6	ns	*	ns
8	ns	*	ns
		2006	
2	*	*	*
4	*	*	*
6	*	*	*
8	*	*	*

LSD $_{(T \leq 0.05)}$
ns = **no significant differences**
- **= significant differences**

In both 2005 and 2006 the different organic fertilisers and different application rates significantly influenced plant height of carrots, except from six to eight weeks after thinning during 2005 where organic fertilisers did not play a role.

2005 Season

In this season, although not significantly, carrot plants that received chicken manure were taller than all other treatments at 2 and 4 weeks after thinning (Table 4.7). Plant height for carrots that received chicken manure was 11.94 cm compared to 11.31 cm for plants that received kraal manure or compost. In general, the height of carrot plants that received inorganic fertiliser was higher than plants that received organic fertiliser.

Table 4.7 Influence of organic fertiliser on plant height (cm) of carrots in 2005

Fertiliser (OF)	Weeks after thinning			
	2	**4**	**6**	**8**
Chicken manure	10.78	11.94	13.06	14.25
Kraal manure	10.09	11.31	12.44	13.56
Composts	10.19	11.31	12.47	13.66
LSD$_{(T \leq 0.05)}$ OF	**0.69**	**0.63**	**ns**	**ns**
2: 3: 4(30)	12.75	14.25	15.50	16.75

Inspection of Table 4.8 shows that different organic fertiliser rates had a positive effect on the height of carrots plants. Organic fertiliser applied at Rates 2 or 3 significantly increased the height of carrot plants compared to plants that did not receive any fertiliser at all four sampling times. Although not significant, an increase in organic fertiliser rate from 2 to 3 restricted the growth of of carrot plants. Two weeks after thinning plant height increased from 8.67 cm for plants that did not receive any fertiliser to 11.88 and 11.63 cm at rate 2 and 3, respectively. The same trend in plant height was observed during week 4, 6 and 8 after thinning.

Table 4.8 Influence of organic fertiliser application rate on plant height of carrots in 2005

Fertiliser application rate (OFR)	Weeks after thinning			
	2	**4**	**6**	**8**
0	8.67	9.75	10.71	11.71
1	9.25	10.42	11.50	12.17
2	11.88	16.33	14.33	15.08
3	11.63	17.83	14.08	14.83
$LSD_{(T\leq 0.05)}$ OFR	**0.88**	**0.87**	**0.86**	**0.93**

2006 Season

The interactions between organic fertiliser and organic fertiliser rates were significant at all four sampling times (Table 4.9). As the rate of chicken manure increased plant height increased. This increase in plant height was, however, only significant where 25 kg 10 m^{-2} chicken manure was applied (2, 6 and 8 weeks after thinning). At eight weeks after thinning, the height of carrot plants increased from 18.00 cm where no chicken manure was applied to 25 cm where 25 kg 10 m^{-2} chicken manure was applied. Kraal manure did not significantly influence the plant height of carrots irrespective of the application rate, at all four sampling times. Although not significant, kraal manure increased the growth of carrots only up to 25 kg 10 m^{-2}. A further increase in kraal manure rate up to 50 kg 10 m^{-2} started to reduce the growth of carrots. This trend was clear at all four sampling times. Fifty or 100 kg 10 m^{-2} compost significantly influenced plant height of carrots, at all four measuring times. At eight weeks after thinning even 25 kg 10 m^{-2} compost had a significant positive effect on plant height of carrots. Plant height increased from 14.25 cm where no compost was applied to 22 cm where 100 kg compost 10 m^{-2} was applied (8 weeks after thinning). Plant height followed the same trend during week 2, 4 and 6 after thinning.

Table 4.9 Influence of organic fertiliser and application rate on plant height of carrots in 2006

Fertiliser (OF)	Fertiliser application rate (OFR) (kg 10 m^{-2})	Weeks after thinning			
		2	**4**	**6**	**8**
Chicken manure	**0**	11.00	13.75	16.00	18.00
	6.25	13.00	15.75	19.00	22.25
	12.5	13.75	16.00	19.00	21.25
	25.0	16.50	19.50	22.50	25.00
Kraal manure	**0**	9.75	12.50	15.25	17.75
	12.5	11.00	13.25	16.00	19.00
	25.0	13.00	15.00	17.50	19.25
	50.0	9.50	11.50	14.00	16.00
Compost	**0**	8.00	10.00	12.50	14.25
	25.0	13.25	15.50	18.50	21.00
	50.0	14.50	17.25	18.75	21.00
	100.0	13.50	16.25	19.25	22.00
LSD$_{(T\leq0.05)}$ OF X OFR		**5.32**	**5.76**	**6.05**	**6.50**
2:3:4(30)	**1.5**	12.75	14.75	17.00	19.20

In both 2005 and 2006 the application of organic fertilisers as well as different application rates influenced the growth of carrots if plant height is used as an index. The tallest carrot plants were obtained where chicken manure and compost were applied at 25 and 50 kg 10 m^{-2}, respectively. Other researchers also reported an increase in plant height with organic fertilisers of other crops such as tomato, *B. oleracea* and *B. carinata* treated with different types of organic fertilisers (Levy & Taylor, 2003; Hu & Barker, 2004; Walker & Bernal, 2004). The height of plants that received organic fertilisers was greater than that of plants that received inorganic fertiliser in 2006 but not in 2005.

4.2.2 YIELD COMPONENTS

In order to establish the yield of carrots, parameters such as fresh and dry mass were measured. A summary of the analysis of variance to determine the effect of different organic fertilisers and application rates on the fresh and dry mass of carrots show that the interactions between organic fertilisers and application rates were only significant for dry mass in 2006 (Table 4.10).

Table 4.10 Summary of the analysis of variance showing the significant effects of organic fertiliser and different rates on fresh and dry mass of carrots in 2005 and 2006

Yield	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF X OFR
		2005	
Fresh mass	ns	ns	ns
Dry mass	ns	ns	ns
		2006	
Fresh mass	ns	*	ns
Dry mass	*	*	*

$LSD_{(T \leq 0.05)}$
ns = no significant differences
*** = significant differences**

Fresh and dry mass of carrots was not significantly influenced by both organic fertilisers as well as different application rates in 2005. It was only in 2006 that the different organic fertiliser rates significantly influenced the fresh mass while both the organic fertiliser and application rate significantly influenced dry mass of carrots.

4.2.2.1 Fresh mass

2005 Season

Fresh mass of carrots was not significantly influenced by the different treatments (Table 4.11). Although not analysed statistically (Chapter 2, Section 2.4.2.2), the highest fresh mass was obtained for carrots treated with inorganic fertiliser (53.33 g). Interestingly, with organic fertilisers the greatest fresh mass was obtained for carrots treated with 100 kg 10 m^{-2} compost (50.74 g), followed by carrots treated with 25 kg 10 m^{-2} kraal manure (49.72 g) and then carrots (48.33 g) treated with 25 kg 10 m^{-2} chicken manure.

Table 4.11 Influence of organic fertiliser and application rate on fresh mass of carrots in 2005

Fertiliser (OF)	Fertiliser application rate (OFR) ($kg\ 10\ m^{-2}$)	Fresh mass (g)
Chicken manure	**0**	45.14
	6.25	43.27
	12.5	46.25
	25.0	48.33
Kraal manure	**0**	43.74
	12.5	46.53
	25.0	49.72
	50.0	44.45
Compost	**0**	43.33
	25.0	46.25
	50.0	46.67
	100.0	50.74
$LSD_{(T \leq 0.05)}$ OF X OFR		ns
2:3:4(30)	**1.5**	53.33

2006 Season

The fresh mass of carrots that received organic fertiliser (Rates 1, 2 or 3) was significantly greater than that of carrots that did not receive any fertiliser (Table 4.12). Fresh mass of carrots increased from 31.09 g (Rate 0) to 50.80 g (Rate 3).

Table 4.12 Influence of organic fertiliser application rate on fresh mass (g) of carrots in 2006

Fertiliser application rate (OFR)	Fresh mass (g)
0	31.02
1	35.74
2	41.37
3	50.81
$LSD_{(T \leq 0.05)}$ OFR	**2.70**

Different types of organic fertilisers did not significantly influence the fresh mass of carrots in both seasons. Application rate of organic fertiliser only significantly influenced fresh mass in the second season. The best response for the fresh mass of carrots was where the highest organic fertiliser rate (Rate 3) was applied. Other researchers also reported on an increase in the fresh mass of carrots when comparing organic with inorganic fertiliser (Blatt, 1991; Zdravkovic *et al.*, 1997; Rembialkowska, 2003). The fresh mass of radish that received organic fertiliser was also greater that those treated with inorganic fertiliser (Lopez *et al*., 1993).

4.2.2.2 Dry mass

2005 Season

Interestingly, although not significant, the dry mass of plants that received organic fertiliser was not necessarily the greatest at the highest application rate (Table 4.13). There was, however, no significant difference between the organic fertilisers and the application rates.

Table 4.13 Influence of organic fertiliser and application rate on dry mass of carrots in 2005

Fertiliser (OF)	Fertiliser application rate (kg 10 m^{-2})	Dry mass (g)
Chicken manure	**0**	7.36
	6.25	6.23
	12.5	6.95
	25.0	6.93
Kraal manure	**0**	6.98
	12.5	7.78
	25.0	7.48
	50.0	7.54
Compost	**0**	7.14
	25.0	6.81
	50.0	6.76
	100.0	7.50
LSD$_{(T\leq0.05)}$ OF X OFR		**ns**
2:3:4(30)	**1.5**	6.95

Season 2006

In this season, the application of different organic fertilisers and different application rates significantly influenced the dry mass of carrots (Table 4.14). As the rate of chicken manure or compost increased, the dry mass of carrots also increased. With chicken manure only an application of 25 kg 10 m^{-2} was significantly greater than carrots that did not receive any fertiliser. Compost at 50 or 100 kg m^{-2} and 50 kg 10 m^{-2} kraal manure also influenced the dry mass of carrots significantly compared to carrots that did not receive any fertiliser.

Table 4.14 Influence of organic fertiliser and application rate on dry mass of carrots in 2006

Fertiliser (OF)	Fertiliser application rate (OFR) (kg 10 m^{-2})	Dry mass (g)
Chicken manure	**0**	4.80
	6.25	5.30
	12.5	5.59
	25.0	7.05
Kraal manure	**0**	5.02
	12.5	4.74
	25.0	5.76
	50.0	6.86
Compost	**0**	4.68
	25.0	5.27
	50.0	5.68
	100.0	5.76
$LSD_{(T\leq0.05)}$ OF X OFR		**0.94**
2:3:4(30)	**1.5**	6.95

Both organic fertilisers and application rates did not significantly influence the dry mass of carrots in the first season but in 2006 the dry mass increased with an increase in the organic fertiliser rates. In 2006 carrots that received 25 kg 10 m^{-2} chicken manure was significantly heavier than carrots that received 100 kg 10 m^{-2} compost. Dry mass of carrots that received inorganic fertiliser compared well with those that received 25 kg 10 m^{-2} chicken manure. However, Pichtel & Bradway (2007) reported that the dry mass of spinach and cabbage that received organic fertiliser was greater than plants that received inorganic fertiliser.

4.2.3 QUALITY COMPONENTS

To evaluate the quality of carrots the following parameters were measured: root length, shoulder diameter and total soluble solids. Carrots were also graded according to size, shape, colour and smoothness of the skin into five classes as was explained earlier in Chapter 2. A summary of the analysis of variance to determine the effect of different organic fertilisers and application rates on the quality parameters of carrots show that the interactions between organic fertiliser and organic fertiliser rate were only significant for total soluble solids in 2005 (Table 4.15).

Table 4.15 Summary of the analysis of variance showing the significant effects of organic fertiliser and different application rates on root length, shoulder diameter and total soluble solids of carrots in 2005 and 2006

Quality	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF X OFR
	2005		
Root length	ns	ns	ns
Shoulder diameter	ns	ns	ns
Total soluble solids	*	*	*
Grading	ns	*	ns
	2006		
Root length	ns	ns	ns
Shoulder diameter	ns	*	ns
Total soluble solids	ns	ns	ns
Grading	*	ns	ns

$LSD_{(T \leq 0.05)}$
ns = no significant differences
*** = significant differences**

Different organic fertilisers and different application rates did not significantly influence the root length of carrots in both 2005 and 2006. The same results were obtained for shoulder diameter of carrots except in 2006 where organic fertiliser rates influenced the shoulder diameter of carrots. Grading was significantly influenced by organic fertiliser rate in 2005 and in 2006 it was influenced by different organic fertilisers.

4.2.3.1 Root length

Season 2005 and 2006

In both seasons root length of carrots was not significantly influenced by the different organic fertiliser treatments (Table 4.16). In 2005, the longest roots (11.9 cm) were obtained where 100 kg 10 m^{-2} compost was applied and in 2006, 6.25 kg 10 m^{-2} chicken manure (11.0 cm).

Table 4.16 Influence of organic fertiliser and application rate on root length of carrots in 2005 and 2006

Fertiliser (OF)	Fertiliser application rate (OFR) (kg 10 m^{-2})	Root length (cm) 2005	Root length (cm) 2006
Chicken manure	**0**	10.5	8.8
	6.25	9.6	11.0
	12.5	9.6	8.8
	25	9.5	9.6
Kraal manure	**0**	9.8	8.0
	12.5	10.1	9.1
	25	10.5	9.5
	50	9.5	10.6
Compost	**0**	9.8	8.8
	25	10.6	9.5
	50	10.4	9.4
	100	11.9	10.8
$LSD_{(T \leq 0.05)}$ OF X OFR		**ns**	**ns**
2:3:4(30)	**1.5**	9.63	12.3

Evanylo *et al*. (2008) reported that the clay percentage of soil was reduced by adding compost to the soil. This may be the reason why the carrots that received compost tended to be slightly longer than the other organic fertiliser treatments but the trend was not clear for both seasons at all rates. Longer carrots were obtained where compost and barnyard manure were applied compared to carrots that received inorganic fertiliser (Warman & Havard, 1996a; Zdravkovic *et al.*, 1997) these results do not correspond with the findings of the present study.

4.2.3.2 Shoulder diameter

2005 Season

Table 4.17 indicates that organic fertiliser and organic fertiliser rates did not significantly influenced the shoulder diameter of carrots and that, although not significantly, the broadest shoulders (2.9 cm) were obtained with 100 kg 10 m^{-2} compost.

Table 4.17 Influence of organic fertiliser and application rate on shoulder diameter of carrots in 2005

Fertiliser (OF)	Fertiliser application rate (OFR) (kg 10 m^{-2})	Shoulder diameter (cm)
Chicken manure	**0**	2.2
	6.25	2.1
	12.5	2.1
	25	2.3
Kraal manure	**0**	2.0
	12.5	2.3
	25	2.5
	50	2.3
Compost	**0**	2.1
	25	2.4
	50	2.4
	100	2.9
$LSD_{(T \leq 0.05)}$ OF X OFR		**ns**
2:3:4(30)	**1.5**	2.8

2006 Season

The shoulders of carrots that received organic fertiliser were broader than carrots that did not receive any fertiliser (Table 4.18). Interestingly, carrots that received the lowest rate of organic fertiliser were larger than those that received higher rates, although not significantly so. Since carrots is a medium feeder its nutrients need was probably met at Rate 1 already.

Organic fertiliser significantly influenced the shoulder diameter in 2006 (Table 4.18). The broadest shoulders were obtained where the lowest (Rate 1) organic fertiliser rate was applied namely 1.8 cm which is still in the acceptable range for pre-pack carrots in South Africa.

Table 4:18 Influence of organic fertiliser rate on shoulder diameter (cm) of carrots in 2006

Organic fertiliser application rate (OFR)	Shoulder diameter (cm)
0	1.4
1	1.8
2	1.7
3	1.7
$LSD_{(T \leq 0.05)}$ OFR	**0.3**

4.2.3.3 Total soluble solids

Season 2005

Interestingly, the total soluble solids of carrots that received organic fertiliser and those that received inorganic fertiliser were lower than plants that did not receive any fertiliser (Table 4.19). The percentage total soluble solids of carrots that received chicken manure at different rates was significantly lower than those that did not receive any fertiliser and this was also true for carrots that received compost. Furthermore, the total soluble solids of carrots that received no fertiliser and those that received either 12.5 or 25 kg kraal manure 10 m^{-2} was significantly greater than carrots that received 50 kg kraal manure 10 m^{-2}. Carrots that received kraal manure showed a decrease in the total soluble solids as the rate of organic fertiliser increased, whereas carrots that received compost showed an increase in total soluble solids. The trend of carrots that received chicken manure was not so clear.

Table 4.19 Influence of organic fertiliser and application rate on the total soluble solids (%) of carrots in 2005

Fertiliser (OF)	Fertiliser application rate (kg 10 m^{-2})	Total soluble solids (%)
Chicken manure	**0**	60.48
	6.25	44.82
	12.5	47.83
	25	40.91
Kraal manure	**0**	60.48
	12.5	58.52
	25	56.66
	50	48.40
Compost	**0**	60.48
	25	42.18
	50	50.68
	100	50.97
LSD$_{(T \leq 0.05)}$ OF X OFR		**6.56**
2:3:4(30)	**1.5**	50.18

Season 2006

As shown in Table 4.20 the different organic fertilisers and different rates did not significantly influence the total soluble solid content of carrots. However, where chicken and kraal manure were applied, the total soluble solid content of carrots tended to be greater than where no fertiliser was applied.

Table 4.20 Influence of organic fertiliser and different application rates on the total soluble solids (%) of carrots in 2006

Fertiliser (OF)	Fertiliser application rate (kg 10 m^{-2})	Total soluble solids (%)
Chicken manure	**0**	29.70
	6.25	33.90
	12.5	37.18
	25	33.97
Kraal manure	**0**	26.74
	12.5	33.83
	25	31.68
	50	28.12
Compost	**0**	30.35
	25	30.04
	50	34.39
	100	25.56
LSD$_{(T \leq 0.05)}$ OF X OFR		**ns**
2:3:4(30)	**1.5**	32.57

In 2005 the application of chicken manure or compost produced carrots with a lower percentage total soluble solids compared to carrots that did not receive any organic fertiliser. Where kraal manure was applied at 50 kg 10 m^{-2} the total soluble solid content of carrots was significantly lower than all other organic fertiliser rates. In 2006 there was no significant difference between the different organic treatments. Although not significant, the highest total soluble solid content was obtained with 12.5 kg 10 m^{-2} chicken manure (37.18%) followed by 50 kg 10 m^{-2} compost (34.39%) and 12.5 kg 10 m^{-2} kraal manure (33.83%). The total soluble solid content of organic fertilised carrots tended to be higher (although not statistically analysed) than organic fertilised carrots. In contrast with these results other researchers reported that the total soluble solids of carrots (Rembialkowska, 1998), *B. campestris* and *B. rape* (Xu *et al*., 2003) that received organic fertiliser was greater than those that received inorganic fertiliser.

4.2.3.4 Grading

2005 Season

Different types of organic fertilisers did not influence the quality (grading) of carrots but different rates significantly influenced it (Table 4.21). Carrots that received organic fertiliser (Class 4) were of a lower grade than those that did not receive any fertiliser (Class 2).

Table 4.21 Influence of organic fertiliser application rate on grading of carrots in 2005

Fertiliser application rate (OFR)	Class
0	2
1	4
2	4
3	4
LSD$_{(T \leq 0.05)}$ OFR	**1**

Class 1 = very smooth **Class 4 = unsmooth**
Class 2 = smooth **Class 5 = very hairy**
Class 3 = average

2006 Season

Compost influenced the quality of carrots negatively in 2006 (Table 4.22). Carrots that received chicken or kraal manure produced relatively good quality roots (Class 2) with a smooth skin compared to carrots that received compost (Class 3).

Table 4.22 Influence of organic fertiliser on grading of carrots in 2006

Fertiliser (OF)	Class
Chicken manure	**2**
Kraal manure	**2**
Compost	**3**
LSD$_{(T \leq 0.05)}$ OF	**1**
2:3:4(30)	**1**

Class 1 = very smooth **Class 4 = unsmooth**
Class 2 = smooth **Class 5 = very hairy**
Class 3 = average

An increase in the organic fertiliser rate promoted the development of hairy carrots compared to those that did not receive any fertiliser in 2005. In 2006, organic fertiliser rates did not significantly influence carrots but carrots that received compost

(Class 3) were of a poorer quality than those that received chicken or kraal manure (Class 2). Carrots that received inorganic fertiliser were graded as Class 1 (very smooth) carrots. All carrots, irrespective of the type of fertiliser and the rate, produced a deep orange colour.

4.3 CONCLUSIONS

From these results it is clear that organic fertilisers influenced the growth, yield and quality of carrots. The growth (number of leaves and plant height) was positively influenced by organic fertiliser and the best response was obtained with chicken manure followed by kraal manure and then compost. The yield (fresh and dry mass) was not significantly influenced during the first year. In the second year, the fresh mass was only significantly influenced by the rate of organic fertiliser and not the type. Dry mass of carrots in the same year was positively influenced by organic fertiliser. Dry mass of carrots that received 25 kg 10 m^{-2} chicken manure, 50 kg 10 m^{-2} kraal manure or 25 kg 10 m^{-2} compost was significantly greater than plants that did not receive any fertiliser. Fresh and dry mass of carrots that received organic fertiliser at the higher rates compared fairly well with plants that received inorganic fertiliser.

Concerning the quality components of carrots, organic fertiliser did not significantly influence root length in both seasons. It was only shoulder diameter that was influenced positively in 2006. Organic fertiliser significantly influenced the total soluble solids negatively in 2005 but not in 2006. The total soluble solids of carrots that received chicken or kraal manure was lower than that of carrots that did not receive any fertiliser. Kraal manure applied at 50 kg 10 m^{-2} also significantly lowered the total soluble solid content of carrots compared to carrots that did not receive any fertiliser. Organic fertilisers however, caused carrots to grade lower (Class 2) than those that did not receive any fertiliser. Carrots that received compost graded even lower in the second season (Class 3).

Organic fertilisers can be recommended for carrot production to improve the growth and yield of carrots. Although the quality of carrots tended to be lower, especially the external quality, the carrots were still within an acceptable range for the pre-pack and fresh produce market in South Africa. From this study, it can be concluded that chicken and kraal manure gave the best results but compost can also be recommended at specific levels, to obtain acceptable yields of a good quality.

CHAPTER 5

SOIL AND CABBAGE (*Brassica oleracea* var. *capitata* L.) NUTRIENT CONTENTS AS INFLUENCED BY ORGANIC FERTILISER

5.1 INTRODUCTION

Soil fertility is the capacity of the soil to provide nutrients for plant growth. The presence of organic matter in the soil is important in maintaining the soil fertility, and to provide a satisfactory environment for plant growth such as water supply, oxygen (aeration), pH, and temperature (Oelhaf,1978). Throughout its production cycle, cabbage mostly requires nutrients such as nitrogen, phosphorus and potassium in varying quantities to support optimal growth and reproduction (Hue, 1995; Guerena, 2006).

Since soil contains insufficient nutrient amounts to produce quality cabbage, it can be supplied to the plant through amending quality organic fertilisers (manures and compost) to the soil. Organic fertilisers enrich the soil with organic matter which improves soil physical properties (water retention, aeration and workability). Furthermore, organic fertilisers provide carbon, which is an important building block for both plant and animal bodies. This carbon is used by micro-organisms in the soil to break down humus and release nutrients. The amount of available nutrients in humus is estimated by measuring the percentage of carbon. Nutrients are taken up by plant roots after they have been converted to inorganic forms i.e. NH_4^+ or NO_3^- (N); $H_2PO_4^-$ or HPO_4^{2-} (P); K^+ (K) by soil microbes (Grubinger, 1999; Lampkin, 2000).

Problems with cabbage growth can occur when the soil $pH_{(KCl)}$ is less than 4.5 or the acid saturation is greater than 5%. Since soil acidity is a parameter that limits crop yield, soil acid saturation, exchangeable acidity and pH should be measured before planting. Acid saturation is the level of exchangeable acidity expressed as a percentage of the total exchangeable cations (K, Ca, Mg, Al and H) and the exchangeable acidity (Al + H) has to be calculated if the pH is less than 4.5. As the soil becomes more acid, the mechanism of conveying nutrients from the soil to the leaves by the roots are restricted because root growth is disturbed and plants cannot take up sufficient water and nutrients. Addition of organic fertilisers has been found to increase the cation exchange capacity and decrease the amount of aluminium in the soil. Since organic matter and clay soil have negatively charged ions they attract positively charged ions (K, Ca, Mg) to their surface and increases the level of total cations available to the plant (Rubeiz *et a*l., 1993; Wong *et al*, 1998).

Like any other crop, cabbage can be analysed to determine the amount of nutrients taken up by the plant. Other studies have shown little or no differences in nutrient uptake between organic and inorganic production systems. This study was carried out to investigate the influence of organic fertilisers on the chemical properties of the soil and the nutrient content of cabbage heads after harvesting.

5.2 RESULTS AND DISCUSSION

5.2.1 Soil chemical properties

The analysis of variance determining the effect of different organic fertilisers and application rates on the chemical properties of the soil after harvesting cabbage, in 2005 and 2006, is summarised in Table 5.1. Different organic fertilisers and application rates did not significantly influence most of the soil properties measured especially in 2005. Only nitrogen, phosphorus, potassium and sulphur were significantly influenced by the interactions between organic fertiliser and application rate.

In 2006, the interaction between organic fertiliser and application rate were only significant for phosphorus and potassium. In the same season phosphorus, potassium, sulphur, magnesium, calcium, total carbon, total cations as well as pH were significantly influenced by both organic fertiliser and application rate. Nitrogen, manganese, zinc, exchange acidity and acid saturation were only significantly influenced by different application rates.

Table 5.1 Summary on the analysis of variance showing the significant effect of organic fertiliser and application rate on the chemical properties of the soil after harvesting cabbage in 2005 and 2006

Nutrients	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF x OFR
	2005		
pH$_{(KCl)}$	ns	ns	ns
N	ns	*	*
P	ns	*	*
K	ns	*	*
S	*	ns	*
Ca	ns	ns	ns
Mg	ns	ns	ns
Zn	ns	ns	ns
Mn	ns	ns	ns
Cu	ns	ns	ns
Total carbon	ns	ns	ns
NIRS organic	ns	ns	ns
Total cations	ns	ns	ns
Acid saturation	ns	ns	ns
Exchange acidity	ns	ns	ns
	2006		
pH$_{(KCl)}$	*	*	ns
N	ns	*	ns
P	*	*	*
K	*	*	*
S	*	*	ns
Ca	*	*	ns
Mg	*	*	ns
Zn	ns	*	ns
Mn	ns	*	ns
Cu	ns	ns	ns
Total carbon	*	*	ns
NIRS organic	ns	ns	ns
Total cations	*	*	ns
Acid saturation	ns	*	ns
Exchange acidity	ns	*	ns

LSD $_{(T\leq 0.05)}$
ns = no significant differences
*** = significant differences**

5.2.1.1 Soil pH$_{(KCl)}$

Soil pH $_{(KCl)}$ increased when it was treated with organic fertiliser in 2006 (Table 5.2). Even the pH of soil treated with inorganic fertiliser was lower compared to organic fertilised soil. Compost treated soil had a significantly higher pH than soil treated with chicken manure. The highest organic fertiliser rate (Rate 3) significantly increased soil pH compared to Rates 0, 1 and 2 with the exception of Rate 2 of chicken manure. Other researchers also reported an increase in soil pH when organic fertilisers such as layer manure, broiler manure, compost, cattle manure and waste perlite were applied (Rubeiz *et al*., 1993; Wong *et al*., 1998; Warman, 2000).

Table 5.2 Influence of organic fertiliser and application rate on soil pH $_{(KCl)}$ after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	4.36	4.37	4.46	4.40
1	4.42	4.47	4.71	4.53
2	4.35	4.53	4.65	4.51
3	4.65	5.01	5.16	4.94
Average (OF)	4.44	4.59	4.74	4.60
$LSD_{(T\leq0.05)}$OF		**0.26**		
$LSD_{(T\leq0.05)}$OFR		**0.34**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		4.24		

5.2.1.2 Total nitrogen

Chicken manure applied at 25 kg 10 m^{-2} significantly increased the total nitrogen content of the soil compared with the 6.25 or 12.5 kg treatments in 2005 (Table 5.3). Although not always significant, the nitrogen content of soil treated with 25 kg 10 m^{-2} chicken manure was also higher than all the other organic fertiliser treatments, irrespective of the application levels. The total nitrogen content of soil that received organic amendments was higher in 2006 than non-treated soil, although this was insignificant. Organic fertiliser applied at Rate 3 significantly increased the nitrogen content of the soil in 2005 compared to Rates 0, 1 and 2. In 2006, the two highest organic fertiliser application rates (2 and 3) significantly increased the nitrogen content of the soil compared with the two lowest rates (0 and 1).

Table 5.3 Influence of organic fertiliser and application rate on the total nitrogen content (%) of the soil after harvesting cabbage in 2005 and 2006

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
		2005		
0	0.139	0.139	0.139	0.139
1	0.131	0.135	0.133	0.132
2	0.136	0.142	0.139	0.139
3	0.154	0.139	0.133	0.142
Average (OF)	0.140	0.139	0.136	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.008**		
$LSD_{(T\leq0.05)}$OFxOFR		**0.018**		
2:3:4(30)		0.13		
		2006		
0	0.133	0.137	0.138	0.136
1	0.133	0.143	0.142	0.139
2	0.141	0.160	0.154	0.152
3	0.161	0.160	0.156	0.159
Average (OF)	0.142	0.150	0.147	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.011**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.14		

Although organic fertilisers tend to increase the nitrogen content of the soil it was not significant compared to soil that did not receive any organic fertiliser amendments in 2005. Interestingly, it was only in 2005 where 25 kg 10 m^{-2} chicken manure significantly increased the nitrogen content compared to some of the other organic fertiliser treatments. The nitrogen values for 2006 were in general higher than in 2005, and this may be an indication of organic fertiliser build-up in the soil over time.

Conflicting results where reported by Canali *et al*. (2004) on citrus and Monaco *et al.* (2007) on maize concerning the influence of different organic fertiliser amendments. In this study, different organic fertiliser types did not significantly influence the total nitrogen content of the soil. However, in their studies they observed a significant increase in the total nitrogen content of the soil where poultry and farm yard manure was applied for 6 and 11 years respectively, compared to soil treated with compost, slurry or plant residues over the same period. The fact that organic fertiliser increased the total nitrogen content of the soil, although not always significant in this study, was supported by results obtained by Warman (2000) and Wells *et al.* (2000) who also reported an increase in soil nitrogen where compost was applied for 12 or 3.5 years respectively to vegetables, compared to soil treated with inorganic fertiliser.

5.2.1.3 Phosphorus

In 2005, 25 kg 10 m^{-2} chicken manure significantly increased the phosphorus content of soil compared to soil that did not receive any organic fertiliser (Table 5.4). Kraal manure and compost, on the other hand, did not significantly increase the phosphorus content of the soil. The phosphorus content of the soil treated with 25 kg 10 m^{-2} chicken manure was significantly higher than where kraal manure (12.5 or 25 kg 10 m^{-2}) or compost (50 or 100 kg 10 m^{-2}) was applied.

Interestingly, in 2006, chicken manure also increased the phosphorus content but this was not as high as the phosphorus content of soil treated with 50 kg 10 m^{-2} kraal manure or 50 or 100 kg 10 m^{-2} compost. The phosphorus content of the soil that received inorganic fertiliser was higher than soil that received organic fertiliser in both seasons, except in 2006 where 100 kg 10 m^{-2} compost was applied.

Table 5.4 Influence of organic fertiliser and application rate on the phosphorus content (mg L^{-1}) of the soil after harvesting cabbage in 2005 and 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2005		
0	15.0	15.0	15.0	15.0
1	14.0	14.3	20.0	16.1
2	15.5	18.8	19.5	17.9
3	37.5	21.5	18.5	25.8
Average (OF)	20.5	17.4	18.3	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**8.0**		
$LSD_{(T\leq0.05)}$OFxOFR		**18.0**		
2:3:4(30)		46.3		
		2006		
0	16.0	15.3	15.8	15.7
1	19.5	24.0	24.8	22.8
2	23.0	37.5	54.5	38.3
3	38.3	54.3	93.0	61.8
Average (OF)	24.2	32.8	47.0	
$LSD_{(T\leq0.05)}$OF		**13.2**		
$LSD_{(T\leq0.05)}$OFR		**16.9**		
$LSD_{(T\leq0.05)}$OFxOFR		**37.9**		
2:3:4(30)		71		

The application of organic fertilisers and different rates increased the percentage of phosphorus in the soil in both 2005 and 2006 although not always significantly so. From these results it is clear that kraal manure and compost increased the phosphorus content of the soil more than chicken manure over a 2 year period, although not always significantly so. This might be an indication of a build up of phosphorus over the two seasons caused by organic fertiliser, but two seasons alone may be still too short to make such conclusions. Phosphorus content of soil treated with 15–60 t ha^{-1} manure for 16 years (cucumbers, cabbage, tomatoes, onions and potatoes) significantly increased (Gontcharenko, 1994) and also soil treated with compost for a period of 12 years (carrots, peppers, onions and tomatoes) (Warman, 2000) or 3½ years (vegetables) (Wells *et al.*, 2000).

5.2.1.4 Potassium

As shown in Table 5.5, 25 kg 10 m^{-2} chicken manure significantly increased the potassium content of the soil compared to soil that received no organic fertiliser and that which received 6.25 or 12.5 kg 10 m^{-2} chicken manure or 12.5 kg 10 m^{-2} kraal manure, in 2005. Kraal manure and compost did not significantly influence the potassium content of the soil in 2005, but in 2006 the potassium content of soil reacted differently. The potassium content of soil that received 100 kg 10 m^{-2} compost was significantly higher than soil that received 25 kg 10 m^{-2} compost, 12.5 kg 10 m^{-2} kraal manure, chicken manure (at all rates) or no organic fertiliser. Kraal manure applied at 50 kg 10 m^{-2} also significantly increased the potassium content compared to soil that did not receive any organic fertiliser and that which received 6.25 or 12.5 kg 10 m^{-2} chicken manure, 12.5 kg 10 m^{-2} kraal manure or 50 kg 10 m^{-2} compost.

Application of different organic fertilisers at different rates tended to increase the potassium content of the soil in both 2005 and 2006. An increase in potassium content of the soil was also observed by Wong *et al*. (1998) after adding 10-75 t ha^{-1} manure (live stock waste mixed with sawdust) for 1 year on *B. cinensis* and *Zea mays*. Similarly, Naramabuye *et al.* (2007) also reported an increase in the potassium content of the soil after adding 10-20 t ha^{-1} cattle manure and grass residues and 2.5-5 t ha^{-1} dolomitic lime for 1 year on maize.

Table 5.5 Influence of organic fertiliser and application rate on the potassium content (mg L^{-1}) of the soil after harvesting cabbage in 2005 and 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2005		
0	115.3	115.3	115.3	115.3
1	125.3	114.3	214.3	151.3
2	134.5	225.0	173.5	177.7
3	356.8	216.0	171.0	247.9
Average (OF)	182.9	167.6	168.5	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**83.3**		
$LSD_{(T\leq0.05)}$OFxOFR		**187.3**		
2:3:4(30)				351.5
		2006		
0	115.5	115.5	82.5	104.5
1	104.0	136.3	119.5	119.9
2	119.8	287.5	257.0	221.4
3	186.8	353.8	416.0	318.8
Average (OF)	131.5	223.3	218.8	
$LSD_{(T\leq0.05)}$OF		**61.4**		
$LSD_{(T\leq0.05)}$OFR		**78.2**		
$LSD_{(T\leq0.05)}$OFxOFR		**175.7**		
2:3:4(30)			302.5	

5.2.1.5 Sulphur

The sulphur content of the soil that received 50 kg 10 m^{-2} compost was significantly higher than soil that received 12.5 or 50 kg 10 m^{-2} kraal manure or 6.25 or 12.5 kg 10 m^{-2} chicken manure in 2005 (Table 5.6). No significant differences were observed in the sulphur content of soil that received organic fertiliser and that which did not receive any organic fertiliser, irrespective of the organic fertiliser type and application rate. Compost significantly increased the sulphur content of soil compared to chicken and kraal manure in 2006. Organic fertiliser applied at Rates 2 and 3 significantly increased the sulphur content compared to application Rates 0 or 1. In both 2005 and 2006 the best response was obtained with 50 kg 10 m^{-2} compost.

Table 5.6 Influence of organic fertiliser and application rate on the sulphur content (%) of the soil after harvesting cabbage in 2005 and 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2005		
0	0.023	0.023	0.023	0.023
1	0.020	0.021	0.023	0.021
2	0.020	0.022	0.027	0.023
3	0.025	0.021	0.024	0.023
Average (OF)	0.022	0.022	0.024	
LSD$_{(T\leq0.05)}$OF		**0.002**		
LSD$_{(T\leq0.05)}$OFR		**ns**		
LSD$_{(T\leq0.05)}$OFxOFR		**0.006**		
2:3:4(30)		0.022		
		2006		
0	0.021	0.019	0.019	0.019
1	0.019	0.021	0.021	0.020
2	0.021	0.023	0.028	0.022
3	0.022	0.023	0.026	0.022
Average (OF)	0.021	0.021	0.023	
LSD$_{(T\leq0.05)}$OF		**0.002**		
LSD$_{(T\leq0.05)}$OFR		**0.003**		
LSD$_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.022		

5.2.1.6 Calcium

It was only in 2006 where organic fertiliser type and application rate significantly influenced the calcium content of the soil. The calcium content of soil treated with compost was significantly higher than soil treated with chicken manure. As the organic fertiliser application rate increased the calcium content of the soil also increased. The calcium content of soil that received organic fertiliser at Rate 3 was significantly greater than all other application rates.

Table 5.7 Influence of organic fertiliser and application rate on the calcium content (mg L^{-1}) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	633.0	607.8	701.0	647.3
1	691.0	761.0	903.5	785.2
2	700.0	836.0	869.3	801.8
3	848.8	913.3	1134.5	965.5
Average (OF)	718.2	779.5	902.1	
$LSD_{(T\leq0.05)}$OF		**128.1**		
$LSD_{(T\leq0.05)}$OFR		**163.1**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		532		

The addition of kraal and compost at different rates significantly influenced the calcium content of the soil in 2006 compared to soil that did not receive any organic fertiliser. Bulluck *et al*. (2002) also reported that the exchangeable calcium in soil treated with different organic fertilisers (composted cottoning trash, composted yard waste or cattle manure) for 2 years on corn, melon and tomatoes was significantly higher than inorganic fertilised soil. Naramabuye *et al.* (2007) also obtained differences between different types of organic fertilisers as was observed in this present study. These researchers obtained higher calcium concentrations in soil treated with 10–20 t ha^{-1} cattle manure and grass residue and 2.5-5 t ha^{-1} dolomitic lime on maize.

5.2.1.7 Magnesium

Again, the different organic fertilisers influenced the magnesium content of soil differently in 2006 (Table 5.8). Different from the results obtained for calcium in the same season, kraal manure and not compost lead to significantly higher magnesium values in soil compared to chicken manure treated soil. Increasing organic fertiliser application rates increased the magnesium content of the soil although not always significantly. The highest application rate of organic fertiliser (Rate 3) significantly increased the magnesium content of the soil compared to soil that did not receive any organic fertiliser.

Table 5.8 Influence of organic fertiliser and application rate on the magnesium content (mg L^{-1}) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	218.0	214.8	223.8	218.8
1	219.3	245.5	260.8	241.8
2	220.3	311.3	227.0	252.8
3	256.8	305.0	309.3	290.3
Average (OF)	228.6	269.1	255.2	
$LSD_{(T\leq0.05)}$OF		**38.1**		
$LSD_{(T\leq0.05)}$OFR		**48.5**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		162.8		

The addition of kraal and compost significantly increased the magnesium content of the soil. The concentration of exchangeable magnesium in the soil was found to be higher with the addition of organic fertilisers (composted cottoning trash, composted yard waste or cattle manure) for two years than with inorganic fertiliser for carrots, peppers, onions and tomatoes (Warman, 2000).

5.2.1.8 Zinc

As shown in Table 5.9, only organic fertiliser application rate significantly influenced the zinc content of the soil in 2006. As the organic fertiliser application rate increased the zinc content of soil also increased, but it is only rate 3 that significantly increased the zinc content (7.8 mg L^{-1}) compared to soil that did not receive any organic fertiliser (4.0 mg L^{-1}). Although not significant, the zinc content of soil that was treated with compost was the highest at all the application rates. Contrary to results of this study, where different organic fertiliser types did not significantly differ in their effect on the zinc content of the soil, Pitchel & Bradway (2007) reported a higher zinc content in soil treated with farmyard manure than in soil treated with composted peat for conventional crops.

Table 5.9 Influence of organic fertiliser and application rate on the zinc content (mg L^{-1}) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	3.7	3.9	3.5	4.0
1	4.2	4.5	5.1	4.6
2	5.4	5.3	6.7	5.8
3	7.8	5.9	9.7	7.8
Average (OF)	5.3	4.9	6.2	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**2.4**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		9.2		

5.2.1.9 Manganese

Manganese content of the soil responded the same as the zinc content in 2006, and it was only organic fertiliser application rate that significantly influenced the manganese content of soil (Table 5.10).

Table 5.10 Influence of organic fertiliser and application rate on the manganese content (mg L^{-1}) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	Organic fertiliser(OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2006		
0	3.0	2.5	3.5	3.0
1	3.3	3.3	4.0	3.4
2	4.5	4.8	5.0	4.8
3	4.3	4.8	4.5	4.5
Average (OF)	3.8	3.8	4.3	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**1.8**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		4.8		

Different from zinc however, organic fertiliser application Rate 2, and not Rate 3, significantly increased the manganese content of the soil compared to soil that did not receive any organic fertiliser. Best results were again obtained with compost (4.3 mg L^{-1}) compared to chicken (3.8 mg L^{-1}) and kraal (3.8 mg L^{-1}) manure, although not significant.

An increase in the manganese content of soil that received organic fertiliser (composted cotton and trash, composted yard waste or cattle manure) for 2 years on corn, melon and tomatoes, was also reported by Bulluck *et al.* (2002). Contrary to this study where organic fertiliser increased the manganese content of the soil, Ortiz *et al.* (2008) reported a reduction in the manganese content of the soil after an application of 10 t ha^{-1} chicken or green manure for 1 year.

5.2.1.10 Total carbon

Type of organic fertiliser and application rate significantly influenced the total carbon percentage of soil in 2006 (Table 5.11). As the organic fertiliser application rate increased the total carbon content of the soil also increased. Organic fertiliser application Rate 3 (2.34%) significantly increased the total carbon content of the soil compared to soil that did not receive any organic fertiliser (2.05%). Soil treated with compost again resulted in significantly higher percentage total carbon (2.27%) than soil treated with chicken manure (2.09%).

Table 5.11 Influence of organic fertiliser and application rate on the total carbon (%) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OF)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	2.04	2.04	2.08	2.05
1	1.97	2.07	2.15	2.06
2	2.07	2.20	2.40	2.22
3	2.29	2.27	2.45	2.34
Average (OF)	2.09	2.15	2.27	
$LSD_{(T\leq0.05)}$OF		**0.15**		
$LSD_{(T\leq0.05)}$OFR		**0.18**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		2.20		

The total carbon content of soil treated with organic fertiliser was comparable with inorganic fertilised soil. Using alternative fertilisers such as composted cottoning trash, composted yard waste or cattle manure for two years Bulluck *et al*. (2002) reported an increased in total carbon content of the soil when compared to inorganic fertilised soil. Rotenberg *et al.* (2005) also reported an increase in the total carbon content of the soil treated with paper mill residual compost for 3 years on cucumbers compared to soil that did not receive any organic fertiliser.

5.2.1.11 Total cations

In 2006 the total cations in the soil followed the same trend as the total carbon (Table 5.12). As the organic fertiliser rate increased the cations in the soil increased and it was again Rate 3 application that significantly increased the cations (8.10 $cmol_c\ L^{-1}$) compared to soil that did not receive any organic fertiliser (5.82 $cmol_c\ L^{-1}$). Compost (7.32 $cmol_c\ L^{-1}$) and kraal manure (6.10 $cmol_c\ L^{-1}$) treated soil contained significantly more cations than soil treated with chicken manure (6.10 $cmol_c\ L^{-1}$). Bado *et al*. (2008) also reported a significant increase in total cations of soil that was treated for 6 years with either 571 kg ha^{-1} rock phosphate or 5 t ha^{-1} manure than soil treated with inorganic fertilizer. Similarly, Olowolafe (2008) also observed an increase in the total cation content of soil treated with municipal waste.

Table 5.12 Influence of organic fertiliser and application rate on the total cations ($cmol_c\ L^{-1}$) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF) Chicken manure	Kraal manure	Compost	Average (OFR)
0	5.75	5.80	5.91	5.82
1	5.88	6.44	7.06	6.46
2	5.91	7.55	6.99	6.81
3	6.95	8.04	9.33	8.10
Average (OF)	6.10	6.96	7.32	
$LSD_{(T\leq0.05)}$OF		**0.82**		
$LSD_{(T\leq0.05)}$OFR		**1.05**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		5.76		

5.2.1.12 Acid saturation

Only organic fertiliser application rate and not the organic fertiliser type significantly influenced the acid saturation of the soil in 2006 (Table 5.13). As the organic fertiliser application rate increased the acid saturation of the soil decreased. The percentage acid saturation of the soil was significantly lower at Rates 2 and 3 application than at Rate 0. Although not significant, the acid saturation of soil treated with compost was also lower than soil treated with chicken or kraal manure. The level of permissible acid saturation, differ from crop to crop and for cabbage production, it should be less than 5% (Allemann & Young, 1993). The acid saturation of all soils that received organic fertiliser was less than 5% and soil that did not receive any organic fertiliser was 10.42% on average. Bado *et al*. (2008) also reported on a decrease in acid saturation of the soil after applying 5 t ha^{-1} manure for a period of 6 years. Smith *et al*. (1999), also found a decrease in acid saturation of the soil after adding 20 t ha^{-1} compost or vermi-compost for 1 year on wheat and oats.

Table 5.13 Influence of organic fertiliser and application rate on the acid saturation (%) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	10.00	14.75	6.50	10.42
1	6.50	4.50	1.25	4.08
2	5.00	1.25	2.00	2.75
3	1.75	1	0.75	1.17
2:3:4(30)				20.25
Average (OF)	5.81	5.38	2.63	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**7.01**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		20.25		

5.2.1.13 Exchange acidity

As shown in Table 5.14, the exchange acidity of the soil followed the same trend as the acid saturation in 2006. Only organic fertiliser application rate significantly influenced the exchange acidity of the soil. Organic fertiliser of Rates 2 and 3 application significantly decreased the exchange acidity of the soil compared to soil that did not receive any organic fertiliser. Bado *et al*. (2008) also reported a reduction in the exchange acidity of soil after the application of 5 t ha^{-1} manure for a period of six years.

Table 5.14 Influence of organic fertiliser and application rate on the exchange acidity (cmalc L^{-1}) of the soil after harvesting cabbage in 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.49	0.71	0.36	0.52
1	0.36	0.27	0.10	0.24
2	0.29	0.08	0.12	0.16
3	0.12	0.07	0.06	0.08
Average (OF)	0.32	0.28	0.16	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.32**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		1.0		

5.2.2 Cabbage head chemical properties

A summary of the analysis of variance determining the effect of different organic fertilisers and application rates on the chemical properties of cabbage heads in 2006 is given in Table 5.15.

Table 5.15 Summary of the analysis of variance showing the significant effect of organic fertiliser and application rate on the chemical properties of cabbage heads in 2006

Nutrients	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF x OFR
N	*	ns	ns
P	ns	ns	ns
K	ns	ns	ns
S	ns	ns	ns
Ca	ns	ns	ns
Na	ns	ns	ns
Mg	ns	ns	ns
Mn	ns	ns	ns
Cu	ns	ns	ns
Fe	ns	ns	ns
Zn	ns	ns	ns
Al	ns	ns	ns
B	ns	ns	ns
C	ns	ns	ns
Moist	ns	ns	ns

$LSD_{(T\leq 0.05)}$
ns = no significant differences
*** = significant differences**

Application of organic fertiliser and application rate did not significantly influence the chemical properties of cabbage heads in 2006. It was only the nitrogen content that was significantly influenced by organic fertiliser. The interactions between organic fertiliser and application rate were also not significant for all the nutrient elements and moisture content of cabbage heads.

5.2.2.1 Nitrogen

As shown in Table 5.16, chicken manure significantly increased the nitrogen content of cabbage heads. The nitrogen content of heads that received chicken manure was 2.45% compared to 2.11 and 2.12% of cabbage heads that received kraal manure or compost, respectively. Plants that received inorganic fertiliser contained more nitrogen (3.74%) than those that received organic fertiliser. Rasool *et al.* (2008) compared the effect of organic and inorganic fertilisers on maize and wheat grain. They reported an increase in the nitrogen content of maize and wheat grain treated with farmyard manure and inorganic fertiliser over a period of 32 years compared to maize and wheat that received no fertiliser.

Table 5.16 Influence of different organic fertilisers and application rate on the nitrogen content (%) of cabbage head

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	2.14	2.14	2.14	2.14
1	2.70	2.24	2.41	2.45
2	2.53	1.95	1.98	2.15
3	2.44	2.11	1.95	2.17
Average (OF)	2.45	2.11	2.12	
$LSD_{(T\leq0.05)}$OF		**0.34**		
$LSD_{(T\leq0.05)}$OFR		**ns**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		3.74		

5.3 CONCLUSIONS

Application of different organic fertilisers at different application rates did not influence most of the chemical properties of the soil in the first season (2005) but their influence was more evident in the second season (2006). Compost significantly influenced most of the chemical properties of the soil. Compost increased the phosphorus, potassium, sulphur, calscium, total carbon and total cation content of the soil in 2006. Kraal manure also significantly increased the phosphorus, potassium and magnesium content of the soil. Chicken manure did not significantly improve the chemical properties of the soil over the 2 years. Organic fertiliser rate influenced nearly all the chemical properties of the soil. It was especially the two highest organic fertiliser rates that significantly influenced the chemical properties of the soil. Organic fertiliser Rates 2 and 3 significantly increased the total nitrogen, potassium, calcium, sulphur, magnesium content and decreased the acid saturation and exchange acidity of the soil. The manganese content of the soil was increased by Rate 2 application of organic fertiliser. Organic fertiliser at Rate 3 significantly increased the phosphorus, zinc, total carbon and total cation content of the soil. Soil pH was also increased by compost and organic fertiliser at Rate 3. Over the short term chicken manure improved the total nitrogen, phosphorus and potassium content of the soil but over the long term, it seems that compost and kraal manure influenced the soil properties more. Although 2 years is a relatively short period, it seems as if compost and kraal manure improved the soil chemical properties more than chicken manure.

The above could be explained on the basis of organic fertiliser application rate and the nutrient content of the different organic amendments. At the end of the growing season in 2005 chicken manure increased the majority of nutrients in the soil. This could be attributed to the higher concentrations of nutrients in chicken manure and its ability to release it rapidly compared to kraal manure or compost. In 2006 compost became prominent in increasing the nutrient content of the soil. This could be attributed to the fact that although the concentration of nutrients in compost are fairly low, greater application levels were used compared to chicken (4 times) and kraal manure (2 times). The rate at which compost releases nutrients is slower than that of chicken manure resulting in a build-up of nutrients over time.

Interestingly, the different organic fertilisers and application rates did not significantly influence the chemical properties of cabbage heads. It was only the nitrogen content that was significantly higher where soil was treated with chicken manure.

CHAPTER 6

SOIL AND CARROT (*Daucus carota* L.) NUTRIENT CONTENTS AS INFLUENCED BY ORGANIC FERTILISERS

6.1 INTRODUCTION

Nutrient uptake by any plant is determined by the availability of nutrients held in the soil, the supply of nutrients to the root surface and the nutrient absorption rate at the root surface. For soil to be able to supply nutrients, it needs to be fertilised. Addition of organic fertiliser to the soil, not only supply nutrients needed by the crop but also creates a favourable environment for microbial activity, i.e. reduces clay percentage and increases soil pH thereby allowing the breakdown of organic matter by soil microbes to release nutrients. Organic fertiliser also releases carbon, which microorganisms use during the process of mineralisation (Oelhaf, 1978; Lampkin, 2000).

Like all other crops, carrots need nutrients such as nitrogen, phosphorus, potassium and microelements to grow. For plants to form proteins, chlorophyll, protoplasm, and enzymes nitrogen is needed, while phosphorus and potassium are needed for root and crop development. For the nutrients to be absorbed by roots it needs to be converted into an inorganic form. Nutrient uptake by roots occurs through mass flow or diffusion. Again nutrient availability, soil microbes and root growth are strongly dependent on soil pH thus any factor such as acid saturation, exchange acidity and pH that could disturb the growth of roots and limit nutrient uptake should be corrected (Taiz & Zeiger, 1991; Riley, 1998). For carrot production, acid saturation should not be greater than 5%.

Many researchers have reported on the influence of organic fertilisers on chemical composition of different vegetables. A four year study was conducted by Abele (1987) on carrots, beetroot and potatoes comparing the effects of organic (composted cattle manure and urine plus biodynamic field preparations) and inorganic fertiliser. The researcher reported that organic fertilised carrots, beetroot and potatoes contained higher phosphorus, potassium, calcium and magnesium content than inorganic fertilised ones. The nitrate content was also lower in the organic fertilised vegetables. In contrast, Hansen (1981) reported no significant difference between organic (biodynamic) and inorganic fertilised potatoes, carrots, beetroot, curly kale and white cabbage for phosphorus, potassium, calcium and magnesium levels, but the study was only for two years. The objective of this study was to investigate the uptake of nutrients by carrots as influenced by organic fertilisers.

6.2 RESULTS AND DISCUSSION

6.2.1 Soil chemical properties

Table 6.1 is a summary of the analysis of variance determining the effect of different organic fertilisers and application rates on the chemical properties of the soil after harvesting carrots in 2005 and 2006.

Inspection of Table 6.1 showed that different organic fertilisers did not significantly influence the chemical properties of the soil in 2005, but application rate did influence it. Organic fertiliser rate significantly influenced the phosphorus, potassium and zinc content of the soil. The interactions between organic fertiliser and application rate were only significant for zinc in 2005. In 2006, organic fertiliser significantly influenced the phosphorus, potassium and sulphur content and the NIRS organic matter of the soil. Different organic fertiliser rates significantly influenced phosphorus, potassium, sulphur, manganese, copper and total cation content of the soil. The interactions between organic fertiliser and application rate were significant for NIRS organic matter of the soil.

Table 6.1 Summary on the analysis of variance showing the significant effects of organic fertiliser and application rate on the chemical properties of the soil after harvesting carrots in 2005 and 2006

Nutrients	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF x OFR
		2005	
$pH_{(KCl)}$	ns	ns	ns
N	ns	ns	ns
P	ns	*	ns
K	ns	*	ns
S	ns	ns	ns
Ca	ns	ns	ns
Mg	ns	ns	ns
Zn	ns	*	*
Mn	ns	ns	ns
Cu	ns	ns	ns
Total carbon	ns	ns	ns
NIRS organic	ns	ns	ns
Total cations	ns	ns	ns
Acid saturation	ns	ns	ns
Exchange acidity	ns	ns	ns
		2006	
$pH_{(KCl)}$	ns	ns	ns
N	ns	ns	ns
P	*	*	ns
K	*	*	ns
S	*	*	ns
Ca	ns	ns	ns
Mg	ns	ns	ns
Zn	ns	ns	ns
Mn	ns	*	ns
Cu	ns	*	ns
Total carbon	ns	ns	ns
NIRS organic	*	ns	*
Total cations	ns	*	ns
Acid saturation	ns	ns	ns
Exchange acidity	ns	ns	ns

LSD $_{(T\leq 0.05)}$
ns = no significant differences
*** = significant differences**

6.2.1.1 Phosphorus

The phosphorus content of the soil increased with an increase in organic fertiliser rates (Table 6.2). In 2005, the highest organic fertiliser rate (Rate 3) and in 2006 the two highest rates (Rates 2 and 3) significantly increased the phosphorus content of the soil. Soil treated with compost in 2006 contained significantly more phosphorus (25.94 mg L^{-1}) than soil treated with chicken manure (11.56 mg L^{-1}).

In the present study, kraal manure and compost significantly influenced the phosphorus content of the soil. In a study conducted by Warman (1986) on timothy hay over a period of 3 years with different manures, it was also reported that different organic fertilisers influenced the phosphorus content of the soil differently. The phosphorus content of the soil was higher where chicken manure was applied compared to where dairy manure or inorganic fertiliser was used. Similarly, Mao *et al*. (2008) and Olowolafe (2008) also observed a higher phosphorus content of the soil where cattle manure or municipal waste was used for a period of 5 years on maize compared to inorganic fertilised soil.

Table 6.2 Influence of organic fertiliser and application rate on the phosphorus content (mg L^{-1}) of the soil after harvesting carrots in 2005 and 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2005		
0	10.75	10.75	10.75	10.75
1	16.00	13.25	11.25	13.50
2	14.00	15.25	12.50	13.92
3	15.25	21.25	19.75	18.75
Average (OF)	14.00	15.13	13.56	
$LSD_{(T\leq0.05)}$OF		ns		
$LSD_{(T\leq0.05)}$OFR		6.80		
$LSD_{(T\leq0.05)}$OFxOFR		ns		
2:3:4(30)		19.00		
		2006		
0	7.50	8.25	6.00	7.25
1	10.25	20.25	21.75	17.42
2	16.00	24.50	29.25	23.25
3	12.50	31.75	46.75	30.33
Average (OF)	11.56	21.19	25.94	
$LSD_{(T\leq0.05)}$OF		9.91		
$LSD_{(T\leq0.05)}$OFR		12.62		
$LSD_{(T\leq0.05)}$OFxOFR		ns		
2:3:4(30)		28.00		

6.2.1.2 Potassium

The potassium content of soil showed the same trend as for phosphorus (Table 6.3). Again, potassium content increased with an increase in organic fertiliser rates in both 2005 and 2006. In 2005, the highest organic fertiliser rate (Rate 3), and in 2006 the two highest rates (Rates 2 and 3) significantly increased the potassium content of the soil. It was only in 2006 where the organic fertiliser significantly influenced the potassium content of the soil, with both kraal manure and compost significantly increasing the potassium content of the soil compared to chicken manure. Warman (2000) reported that the potassium content of the soil planted with timothy hay increased when treated with 89.6 t ha^{-1} dairy manure (wet) for 3 years compared to soil that was not treated with organic fertiliser and one that was treated with inorganic fertiliser.

Table 6.3 Influence of organic fertiliser and application rate on the potassium content (mg L^{-1}) of the soil after harvesting carrots in 2005 and 2006

Organic fertiliser rate (OFR)	Organic fertilser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
		2005		
0	122.25	122.25	122.25	122.25
1	211.50	236.00	144.50	197.33
2	204.75	257.25	145.25	202.42
3	220.00	317.50	274.75	270.75
Average (OF)	189.63	233.25	171.69	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**91.09**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		377.25		
		2006		
0	124.75	116.75	99.25	113.58
1	124.50	207.25	181.25	171.00
2	172.25	274.75	224.50	223.83
3	164.75	347.25	333.25	281.75
Average (OF)	146.56	209.56	236.50	
$LSD_{(T\leq0.05)}$OF		**57.87**		
$LSD_{(T\leq0.05)}$OFR		**73.66**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		283.50		

6.2.1.3 Sulphur

In 2006, the sulphur content of soil increased with an increase in the organic fertiliser rate (Table 6.4). Organic fertiliser at Rate 3 significantly increased the sulphur content (0.024%) of the soil compared to soil that did not receive any organic fertiliser (0.021%). Kraal manure significantly increased the phosphorus content of the soil (0.024%) compared to soil that received chicken manure (0.021%)

Table 6.4 Influence of organic fertiliser and application rate on the sulphur content (%) of the soil after harvesting carrots in 2006

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	0.020	0.021	0.020	0.021
1	0.020	0.022	0.023	0.022
2	0.021	0.024	0.022	0.022
3	0.022	0.022	0.029	0.024
Average (OF)	0.021	0.024	0.022	
LSD$_{(T\leq0.05)}$OF		**0.003**		
LSD$_{(T\leq0.05)}$OFR		**0.003**		
LSD$_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.021		

Zinc

The highest zinc content was obtained in soil that was treated with 12.5 kg 10 m^{-2} chicken manure in 2005 (Table 6.5). Inorganic fertilised soil contained more zinc than soil treated with organic fertiliser. Rasoli & Forghani (2006) also reported that different organic fertilisers influenced the zinc content of the soil differently. They observed that farmyard manure applied for 1 year on maize, increased the zinc content significantly more than city compost, *Pongamia* and *Glyricidia* litter.

Table 6.5 Influence of organic fertiliser and application rate on the zinc content (mg L^{-1}) of the soil after harvesting carrots in 2005

Organic fertiliser rate (OFR)	Organic fertilser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	2.50	2.50	2.50	2.50
1	3.68	4.83	2.93	3.81
2	5.43	3.35	2.55	3.78
3	2.98	3.23	3.43	3.20
Average OF	3.64	3.48	2.85	
$LSD_{(T \leq 0.05)}$OF		**ns**		
$LSD_{(T \leq 0.05)}$OFR		**1.26**		
$LSD_{(T \leq 0.05)}$OFxOFR		**2.84**		
2:3:4(30)		5.47		

6.2.1.4 Manganese

As shown in Table 6.6, the manganese content of the soil increased as the organic fertiliser rate increased in 2006. The two highest organic fertiliser rates (Rates 2 and 3) significantly increased the manganese content of the soil. Although there were no significant difference amongst the organic fertilisers, the highest soil manganese content was obtained in soil that was treated with 100 kg 10 m^{-2} compost. Sur & Das (2006) also reported an increase in the manganese content of the soil after 1 year where 4 t ha^{-1} manure was applied together with 0.5 kg ha^{-1} zinc on maize. Rasoli & Forghani (2006) reported that different organic fertilisers reacted differently in terms of manganese content of the soil and that is in contrast with the present study's results. Manganese content of the soil, planted with maize, was higher where farmyard manure was applied for 1 year than in soils treated with city compost, *Pongamia* and *Glyricidia* litter.

Table 6.6 Influence of organic fertiliser and application rate on the manganese content (mg L^{-1}) of the soil after harvesting carrots in 2006

Organic fertiliser rate (OFR)	Organic fertilser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	3.25	3.00	3.00	3.08
1	3.75	3.75	3.75	3.75
2	3.75	4.25	4.25	4.08
3	4.25	4.00	4.50	4.25
Average (OF)	3.75	3.75	3.88	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.73**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		3.7		

6.2.1.5 Copper

Copper reacted the same way as manganese during 2006 (Table 6.7). The two highest organic fertiliser rates significantly increased the copper content of the soil. Copper content of the soil increased from 1.82 mg L^{-1} at Rate 0 to 2.00 and 2.09 mg L^{-1} for Rates 2 and 3, respectively. Sur & Das (2006) reported that 4 t ha^{-1} manure plus 0.5 kg ha^{-1} zinc applied for 1 year on cabbage also increased the copper content of the soil. A similar result of an increase in copper of soil after using manure applied at 1% C was also reported by Rasoli & Forghani (2006). However, they also reported on differences in response of different organic fertilisers which was not observed in the present study. The copper content of the soil increased significantly when farmyard compost was used for one year on maize than where city compost, *Pongamia* or *Glyricidia* litter was used.

Table 6.7 Influence of different organic fertiliser and application rate on the copper content (mg L^{-1}) of the soil after harvesting carrots in 2006

Organic fertiliser rate (OFR)	Organic fertiliser (OF) Chicken manure	Kraal manure	Compost	Average (OFR)
0	1.80	1.80	1.85	1.82
1	1.95	1.88	1.95	1.93
2	1.93	1.98	2.10	2.00
3	2.05	2.03	2.20	2.09
Average (OF)	1.93	1.92	2.03	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.16**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		1.90		

6.2.1.6 NIRS organic matter

Compost applied at 100 kg 10 m^{-2} significantly increased the NIRS organic matter of the soil compared to soil that did not receive any organic fertiliser or chicken manure (Table 6.8). Warman (1986) reported a significant increase in the organic matter of the soil when applying 89.6 t ha^{-1} (wt) dairy manure or 33 t ha^{-1} (wt) chicken manure compared to inorganic fertilised soil. The NIRS organic matter of soil treated with 20-40 t ha^{-1} farmyard manure for 40 years was also high (Morari *et al.*, 2006).

Table 6.8 Influence of organic fertiliser and application rate on the NIRS organic matter (%) of the soil after harvesting carrots in 2006

Organic fertiliser rate (OFR)	Organic fertilser (OF) Chicken manure	Kraal manure	Compost	Average (OFR)
0	2.48	2.53	2.40	2.47
1	2.23	2.65	2.80	2.56
2	2.48	2.73	2.48	2.56
3	2.23	2.68	3.28	2.73
Average (OF)	2.35	2.64	2.74	
$LSD_{(T\leq0.05)}$OF		**0.24**		
$LSD_{(T\leq0.05)}$OFR		**ns**		
$LSD_{(T\leq0.05)}$OFxOFR		**0.70**		
2:3:4(30)		2.15		

6.2.1.7 Total cations

The total cations increased with an increase in organic fertiliser rate (Table 6.9). Organic fertiliser application rate significantly increased the total cation content of the soil from 6.58 $cmol_c\ L^{-1}$ at Rate 0, to 8.05 $cmol_c\ L^{-1}$ at Rate 3. Olowolafe (2008) also reported an increase in the total cations and cation exchange capacity of soil treated with municipal waste for one year compared to inorganic treated soil. In the present study, the total cation content of soil treated with inorganic fertiliser was also lower than the organic fertilised treated soil.

Table 6.9 Influence of organic fertiliser and application rate on total cations ($cmol_c\ L^{-1}$) in the soil after harvesting carrots in 2006

Organic fertiliser rate (OFR)	Organic fertilser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	6.59	6.66	6.51	6.58
1	7.11	7.13	7.03	7.09
2	6.4	7.73	7.69	7.27
3	7.32	8.45	8.39	8.05
Average (OF)	6.85	7.41	7.49	
$LSD_{(T\leq0.05)}OF$		**ns**		
$LSD_{(T\leq0.05)}OFR$		**1.20**		
$LSD_{(T\leq0.05)}OFxOFR$		**ns**		
2:3:4(30)		5.73		

6.2.2 Carrot root chemical properties

A summary of the analysis of variance determining the effect of different organic fertilisers and different application rates on the chemical properties of carrot roots after harvesting in 2006 is given in Table 6.10. This data was only collected in 2006.

Table 6.10: Summary on the analysis of variance showing the significant effect of organic fertiliser and application rate on the chemical properties of carrot roots after harvesting in 2006

Nutrients	Organic fertiliser (OF)	Organic fertiliser rate (OFR)	OF x OFR
N	*	*	*
P	ns	*	ns
K	ns	ns	ns
S	ns	*	ns
Ca	*	*	ns
Na	ns	ns	ns
Mg	ns	*	ns
Mn	ns	*	ns
Cu	ns	ns	ns
Fe	*	ns	ns
Zn	ns	ns	ns
Al	ns	ns	ns
C	*	*	*
Moist	ns	ns	ns

LSD $_{(T\leq 0.05)}$
ns = no significant differences
*** = significant differences**

As shown in Table 6.10, application of different organic fertilisers and different application rates significantly influenced the content of some chemical properties of carrot roots. The interactions between organic fertiliser and application rate were only significant for total nitrogen and carbon content of the carrot roots. Organic fertiliser significantly influenced the calcium and iron content of carrot roots, while organic fertiliser application rate significantly influenced the phosphorus, sulphur, calcium, magnesium and manganese content of carrot roots.

6.2.2.1 Nitrogen

As shown in Table 6.11, the nitrogen content of carrots increased with chicken manure or compost applications while kraal manure only marginally increased the nitrogen content. Carrots that received 100 kg 10 m^{-2} compost or 25 kg 10 m^{-2} chicken manure contained significantly more nitrogen than all the other organic treatments including carrots that did not receive any organic fertiliser. In a study conducted by Warman & Havard (1997) where compost (170 kg N ha^{-1}) was applied over a period of 3 years, the nitrogen content of carrot roots significantly increased compared to carrots grown in inorganic fertilised soil.

Table 6.11 Influence of organic fertiliser and application rate on the nitrogen content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.85	0.82	0.85	0.84
1	1.0	0.9	0.88	0.92
2	0.95	0.93	0.95	0.94
3	1.15	0.95	1.29	1.13
Average OF	0.98	0.90	0.99	
LSD$_{(T \leq 0.05)}$OF		**0.07**		
LSD$_{(T \leq 0.05)}$OFR		**0.09**		
LSD$_{(T \leq 0.05)}$OFxOFR		**0.09**		
2:3:4(30)		0.96		

6.2.2.2 Phosphorus

The phosphorus content of carrots was only significantly influenced by the organic fertiliser rate (Table 6.12). The two highest application rates (Rates 2 and 3) significantly increased the phosphorus content (0.36 and 0.38% respectively) of carrot roots compared to carrots that did not receive any organic fertiliser (0.33%). According to Lairon *et al.* (1986) the phosphorus content of potatoes and carrots treated with organic fertiliser for two seasons was higher than those treated with inorganic fertiliser.

Table 6.12 Influence of organic fertiliser and application rate on the phosphorus content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.31	0.34	0.34	0.33
1	0.33	0.36	0.33	0.34
2	0.34	0.37	0.36	0.36
3	0.36	0.39	0.38	0.38
Average (OF)	0.34	0.36	0.35	
LSD$_{(T \leq 0.05)}$OF		**ns**		
LSD$_{(T \leq 0.05)}$OFR		**0.03**		
LSD$_{(T \leq 0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.32		

6.2.2.3 Sulphur

The organic fertiliser application rate significantly influenced the sulphur content of carrots (Table 6.13), but it was only the highest application rate that was significantly higher than Rates 1 and 2 and not Rate 0. Warman & Havard (1997) also reported that the sulphur content of carrot roots increased when treated with compost (170 kg N ha^{-1}) over a period of 3 years compared to carrot roots that received inorganic fertiliser. In the present study, the sulphur content of the inorganic treated soil was lower than the organic treated soil.

Table 6.13 Influence of organic fertiliser and application rate on the sulphur content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.16	0.21	0.16	0.18
1	0.17	0.16	0.15	0.16
2	0.16	0.15	0.21	0.17
3	0.23	0.24	0.20	0.22
Average (OF)	0.18	0.19	0.18	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.05**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.13		

6.2.2.4 Calcium

Both organic fertiliser and application rates significantly influenced the calcium content of carrot roots (Table 6.14). As the organic fertiliser rate increased the calcium content of carrots significantly decreased, irrespective of the application rate when compared to carrots that did not received any organic fertiliser. Carrots treated with chicken manure contained significantly less calcium than carrots treated with kraal manure or compost. Contrary to the above results, Lampkin (2000) found high calcium levels in organic grown products than inorganic grown ones.

Table 6.14 Influence of organic fertiliser and application rate on calcium content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.28	0.30	0.30	0.30
1	0.28	0.27	0.28	0.28
2	0.25	0.26	0.27	0.26
3	0.26	0.30	0.26	0.27
Average (OF)	0.27	0.28	0.28	
$LSD_{(T\leq0.05)}$OF		**0.01**		
$LSD_{(T\leq0.05)}$OFR		**0.02**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.27		

6.2.2.5 Magnesium

As shown in Table 6.15, organic fertiliser rate significantly influenced the magnesium content of carrot roots. Roots that received organic fertiliser at Rate 2 had significantly lower magnesium than all the other organic fertiliser treatments including the 0 rate. In this study, the inorganic treated carrots contained lower magnesium levels than carrots that did not receive any fertiliser but were in the same range than the organic treated carrots. However, Alfoldi *et al.* (1996) reported that the magnesium content of potatoes that received fresh and composted farmyard manure plus slurry for three years was lower than inorganic fertilised potatoes.

Table 6.15 Influence of organic fertiliser and application rate on magnesium content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	0.14	0.15	0.15	0.15
1	0.14	0.14	0.13	0.13
2	0.13	0.13	0.11	0.12
3	0.12	0.14	0.14	0.13
Average (OF)	0.13	0.14	0.13	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**0.01**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		0.13		

6.2.2.6 Manganese

The manganese content of carrot roots tended to react the same as the magnesium content (Table 6.16). Organic fertiliser Rate 2 significantly decreased the magnesium content of carrots compared to carrots that did not received any fertiliser. In the present study, carrots that received inorganic fertiliser tended to contained more manganese than those that received organic fertiliser. Warman & Havard (1997) obtained higher manganese levels in carrots treated with compost (170 kg N ha^{-1}) over a period of 3 years compared to inorganic fertilised carrots.

Table 6.16 Influence of organic fertiliser and application rate on the manganese (mg kg^{-1}) content of carrot roots

Organic fertiliser rate (OFR)	**Organic fertiliser (OF)**			**Average (OFR)**
	Chicken manure	**Kraal manure**	**Compost**	
0	21.25	20.75	22.75	21.58
1	18.50	23.25	20.00	20.58
2	16.00	16.50	19.25	17.25
3	17.00	21.00	17.25	18.42
2:3:4(30)		22.50		
Average (OF)	18.19	20.38	19.81	
$LSD_{(T\leq0.05)}$OF		**ns**		
$LSD_{(T\leq0.05)}$OFR		**4.01**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		22.50		

6.2.2.7 Iron

Iron content of carrots that received kraal manure was significantly higher than those that received compost (Table 6.17). Although not significant, the iron content of carrots also decreased with an increase in organic fertiliser rates. Smith (1993) and Worthington (1998) reported a higher iron content in organic grown vegetables than inorganic grown vegetables, while in the present study this was also observed where kraal manure and chicken manure was applied but not for compost.

Table 6.17 Influence of organic fertiliser and application rate on iron content (mg kg^{-1}) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	187.50	234.25	179.00	200.25
1	206.00	231.00	135.00	191.00
2	194.25	181.00	148.00	174.42
3	143.25	190.25	141.75	158.42
Average (OF)	182.75	209.13	151.19	
$LSD_{(T\leq0.05)}$OF		**41.21**		
$LSD_{(T\leq0.05)}$OFR		**ns**		
$LSD_{(T\leq0.05)}$OFxOFR		**ns**		
2:3:4(30)		149.5		

6.2.2.8 Total carbon

As shown in Table 6.18, the carbon content of carrot roots that received 6.25 kg 10 m^{-2} chicken manure was significantly higher than all the other treatments except where 50 kg 10 m^{-2} chicken manure was applied (Table 6.32). The total carbon content of carrots was not significantly influence by kraal manure or compost at different applications rates. Strauss *et al*. (2003) also reported on the difference between different organic fertilisers. They reported higher carbon in vegetables treated with co-compost (sludge and municipal organic waste) than that of refuse compost applied for 2 years.

Table 6.18 Influence of organic fertiliser and application rate on the carbon content (%) of carrot roots

Organic fertiliser rate (OFR)	Organic fertiliser (OF)			Average (OFR)
	Chicken manure	Kraal manure	Compost	
0	40.93	41.11	40.19	40.74
1	42.89	40.96	41.11	41.65
2	41.34	40.81	41.30	41.15
3	41.62	40.41	40.38	40.80
Average (OF)	41.69	40.82	40.75	
$LSD_{(T\leq0.05)}$OF		**0.54**		
$LSD_{(T\leq0.05)}$OFR		**0.69**		
$LSD_{(T\leq0.05)}$OFxOFR		**1.55**		
2:3:4(30)		40.63		

6.3 CONCLUSIONS

The chemical properties of the soil were mainly influenced during the 2006 season and it was clear that organic fertiliser rate influenced most of the chemical properties. Organic fertiliser Rates 2 and 3 significantly increased the phosphorus, potassium, manganese and copper content of the soil and Rate 3 also significantly increased the sulphur, total cation and NIRS organic matter of the soil. Compost significantly increased the phosphorus, potassium and NIRS organic matter of the soil when compared to chicken manure. Kraal manure also significantly increased the potassium and sulphur content of the soil more than chicken manure. The significant role of chicken manure was only visible in 2005 for the zinc content of the soil.

Both the organic fertiliser and application rate influenced the chemical properties of carrot roots. The chemical properties of carrot roots were mainly influenced by organic fertiliser application rates. The nitrogen and phosphorus content of carrots that receive the two highest application rates (Rates 2 and 3) were significantly higher than those that did not received any organic fertiliser and the calcium and manganese content was significantly lower at all three application rates compared to Rate 0. Organic fertiliser application Rate 3 significantly increased the sulphur content of carrot roots compared to the other application rates, while the manganese content of carrots that received organic fertiliser at Rate 2 was significantly lower than those that did not receive any organic fertiliser. Organic fertilisers were not consistent in their influence on the chemical properties of carrots. However, 25 kg 10 m^{-2} chicken manure and 100 kg 10 m^{-2} compost significantly increased the nitrogen content while the calcium content was significantly lowered where chicken manure was applied compared to kraal manure and compost. Kraal manure significantly increased the iron content of carrot roots compared to compost and the carbon content of carrots that received 6.25 kg 10 m^{-2} chicken manure was also significantly higher than most other organic fertiliser rates.

CHAPTER 7

SUMMARY AND RECOMMENDATIONS

7.1 SUMMARY

7.1.1 Influence of organic fertiliser on the yield and quality of cabbage (*Brassica oleracea* var. *capitata* L.)

The type of organic fertiliser did not affect early growth of cabbage (number of leaves and plant height) as much as it influenced the yield components (fresh and dry mass) and quality components (grading and head diameter). As was expected, the rate of organic fertiliser applied significantly influenced almost all the parameters measured. It was, however only plant height that tended to decrease when organic fertiliser rate increased from Rate 2 to 3.

Cabbage responded the best to chicken manure when fresh and dry mass were used as indexes. In 2005, fresh and dry mass of cabbage that received chicken manure was significantly more than cabbage that received kraal manure or compost. Chicken manure resulted in cabbage that was even heavier than cabbage that received inorganic fertiliser. In 2006, the fresh (≥12.5 kg 10 m^{-2} chicken manure) and dry mass (≥25 kg 10 m^{-2} chicken manure) of cabbage that received chicken manure was significantly greater than all the other treatments. Fresh and dry mass of cabbage was also more where chicken manure was applied (2006) at 12.5 or 25 kg 10 m^{-2} than where inorganic fertiliser was applied.

The quality of cabbage that received organic fertiliser compared well to plants that received inorganic fertiliser. Organic fertiliser types did not play an important role, it was more the application rate that influenced the quality positively. Chicken manure resulted in cabbage heads that were Grade 1 at all the rates applied while kraal manure and compost were Grade 1 at Rates 2 and 3. Different organic fertilisers also did not influence cabbage head diameter in the first season (2005) but in 2006 cabbage heads that received ≥12.5 kg chicken manure 10 m^{-2} were significantly larger than all the other treatments. Head diameter of cabbage that received chicken manure and those that received inorganic fertiliser was of the same size. An increase in organic fertiliser rates also had a positive effect on cabbage head diameter irrespective of the type of organic fertiliser.

7.1.2 Influence of organic fertiliser on the yield and quality of carrots (*Daucus carota* L.)

In both 2005 and 2006 organic fertiliser application as well as different application rates influenced the growth of carrots when number of leaves and plant height were used as index. The best response on the number of leaves and plant height was obtained from plants that received chicken manure followed by kraal manure and then compost. In general, higher organic fertiliser rates resulted in better growth response, but kraal manure and compost tended to influence plant height negatively when the application rate increased from 2 to 3. The growth (number of leaves and plant height) of inorganic fertilised plants responded better than plants that received organic fertiliser except for plant height in 2006.

The organic fertiliser type and application rate did not influence the fresh and dry mass of carrots in 2005. In the second year (2006) increased organic fertiliser rates significantly increased the fresh mass of carrots. Dry mass of carrots that received the 25 kg 10 m^{-2} chicken or 50 kg 10 m^{-2} kraal manure was significantly higher than carrots that did not receive any fertiliser. However, the dry mass of carrots that received compost, even at a low rate (25 kg 10 m^{-2}), was significantly more than carrots that did not receive any fertiliser. Dry mass of carrots that received organic fertiliser compared well with carrots that received inorganic fertiliser, although dry mass of carrots that received 25 kg 10 m^{-2} chicken manure were greater than carrots that received inorganic fertiliser.

Carrot length was not significantly influenced by, either organic fertiliser type or the rate of application, in both seasons. Interestingly, it was only in 2006 where shoulder diameter of carrots was significantly influenced by organic fertiliser at Rate 1. In the first season (2005) the total soluble solids of carrots were negatively influenced by the organic fertiliser type and rate but not in 2006. The total soluble solid contents of carrots that received chicken manure or compost was significantly lower than carrots that did not receive any fertiliser, and this was also true for carrots that received 50 kg 10 m^{-2} kraal manure. Carrots that received organic fertiliser at all three rates graded significantly lower (Class 4) than carrots that did not received any fertiliser (Class 2) in 2005. In the second season (2006) carrots that receive chicken or kraal manure graded as Class 2 carrots but carrots that received compost graded lower (Class 3).

7.1.3 Soil and cabbage (*Brassica oleracea* var. *capitata* L.) nutrient content as influenced by organic fertilisers

The soil chemical properties were hardly influenced by organic fertiliser or application rate in the first season (2005), but in the second year (2006) the different organic fertilisers and application rates influenced some of the chemical properties of the soil.

Soil $pH_{(KCl)}$ was only influenced in the second season (2006). The soil $pH_{(KCl)}$ where chicken manure was applied was significantly lower than where compost was applied. Chicken manure at 25 kg 10 m^{-2} significantly increased the nitrogen, phosphorus and potassium content of the soil while 50 kg 10 m^{-2} significantly increased the sulphur content of the soil. In 2006, chicken manure was less prominent while compost and kraal manure significantly improved the chemical properties of the soil. Compost significantly increased the nitrogen, phosphorus, potassium, sulphur and calcium content of the soil. Kraal manure, however, also significantly increased the phosphorus, potassium and magnesium content of the soil. In most cases it was the two highest organic fertiliser rates that significantly influenced the chemical properties. Interestingly, organic fertiliser did not significantly influence the NIRS organic matter of the soil over a 2 year period.

Neither organic fertiliser nor fertiliser rate significantly influenced most of the chemical properties of cabbage heads. It was only chicken manure that significantly influenced the nitrogen content of cabbage compared to compost and kraal manure.

7.1.4 Soil and carrot (*Daucus carota* L.) nutrient content as influenced by organic fertilisers

The soil chemical properties where carrots were planted and treated with organic fertiliser at different application rates was not influenced to the same extend as cabbage. Chicken manure at 12.5 kg 10 m^{-2} significantly increased the zinc content of the soil in the first season (2005). In 2006, it was again compost that significantly increased some of the chemical properties of the soil. Compost significantly increased the phosphorus, potassium content and NIRS organic matter of the soil compared to chicken manure. However, kraal manure only significantly increased the sulphur content of the soil.

The two highest organic fertiliser rates influenced some of the chemical properties of the soil in 2006. Phosphorus, potassium, manganese and copper content of the soil significantly increased where organic fertiliser was applied at Rates 2 and 3, while Rate 3 also increased sulphur content and the NIRS organic matter of the soil.

Organic fertiliser and application rate influenced the chemical properties of carrot roots more than cabbage. It was, again, the application rates that had a more pronounced effect on the chemical properties of carrots. The nitrogen content of carrots was significantly increased by 100 kg 10 m^{-2} compost or 25 kg 10 m^{-2} chicken manure. Kraal manure increased the iron content significantly more than compost, while 6.25 kg 10 m^{-2} chicken manure increased the carbon content of soil significantly more than all the other organic fertiliser treatments. Calcium, magnesium and manganese content of the soil, however, decreased as the organic fertiliser rate increased. Organic fertiliser applied at Rate 2 significantly decreased all three of the above mentioned elements, while Rates 1 and 3 significantly decreased the calcium and magnesium content of the soil.

7.2 RECOMMENDATIONS

- Results of the present study on cabbage showed that chicken manure performed better than kraal manure and compost. The response of cabbage plants to different organic fertilisers and different application rates showed that the optimum fertiliser application rate for chicken manure was 12.5–25 t ha^{-1}; 25–50 t ha^{-1} for kraal manure and 50–100 t ha^{-1} compost on the soil type used in this study.
- Considering the response of carrots in terms of growth, yield and quality to different organic fertilisers and application rates showed that 12.5–25 kg 10 m^{-2} chicken manure, 25–50 kg 10 m^{-2} kraal manure or 50 kg 10 m^{-2} compost showed to be the optimum levels for the type of soil used in this study.

- Because of the inconsistency in the results on the influence of organic fertiliser and application rate on soil chemical properties, no clear recommendation can be made for either cabbage or carrots. It can, however, be said that compost seemed to increase most of the properties more than chicken manure after application for 2 years, and in most cases at the two highest application rates.

In retrospect, this study was only done over a 2 year period and on one soil type. The influence of organic fertiliser and application rate over a longer period, especially concerning the soil chemical properties, need further investigation and also on different soil types. This may give more clear results for better recommendations for the future.

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