

**EFFECT OF VERMICOMPOST ON GROWTH AND YIELD OF CABBAGE
(*BRASSICA OLERACEAE* VAR. *CAPITATA*)**

by

RAMADIMETŠE REBONE LESUFI



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Supervisor : Ms. N.N. Buthelezi

Co-Supervisor: Prof I.K. Mariga

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DEDICATION

This work is dedicated to my fiancé and my father who believed in me and supported me throughout these degree studies

DECLARATION

I declare that EFFECT OF VERMICOMPOST ON GROWTH AND YIELD OF CABBAGE (BRASSICA OLERACEAE VAR. CAPITATA) is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references and that this work has not been submitted before for any other degree at any other institution.

Candidate: Ramadimetše Rebone Lesufi

Signature

Date

Supervisor: Ms NN Buthelezi

Signature

Date

Co – Supervisor: Prof IK Mariga

Signature

Date

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Life is an express road and overtaking is allowed_ BRAVO!!!!

ABSTRACT

An experiment was conducted to evaluate the effect of vermicompost on cabbage growth and yield. Vermicompost (VC) was applied at 2500 kg/ha and was compared to one organic {vita grow (VG) [N:P:K 2:3:2 (16)] and one chemical fertiliser (CF) (N:P:K 2:3:2(22))} which were both applied at 1500 kg/ha. The other treatments were prepared as mixtures of the three fertilisers (i.e. vermicompost and vita grow; vita grow and chemical fertiliser as well as vermicompost and chemical fertiliser) at 50% recommended rate, with no fertiliser treatment as a control. The trial was laid out in a randomised complete block design with three replicates. Chemical fertiliser achieved the highest chlorophyll content (80.6 nmol/mg) which was significantly higher than the other treatments. Vermicompost and the control had the least chlorophyll content at 58.6 and 55.8 nmol/mg, respectively. VC+VG, CF and CF+VC achieved the highest numbers of marketable heads while the control had the least. VC+VG, CF and CF+VC had more than 60% of the plants producing marketable heads whilst VC and VG had less than 40% of the plants producing marketable heads. The control only had 19.93% of the plants producing marketable heads. Range of marketable heads ranged from 2.82 t/ha for the control to 12.7 t/ha for CF. VC+VG, CF and CF+VC achieved marketable yields above 10.0 t/ha. VC and VG achieved 5.45 and 8.28 t/ha. The results thus show that use of chemical fertiliser or the combinations of VC and VG and that of CF and VC are the ones that can be recommended for cabbage production.

Key words: vermicompost, growth, yield, cabbage, fertiliser

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CHAPTER 1

INTRODUCTION

Cabbage (*Brassica Oleraceae* var. *capitata*) is a commonly grown vegetable throughout the world, including most parts of South Africa. It was originally grown for its medicinal purposes to cure diseases but presently is used for human consumption due to its nutritional value (Pavla and Pokluda, 2008).

To ascertain this nutritional quality, cabbage feeds heavily (More, 2006 and Semuli, 2005). Making availability of soil nutrients in the soil is very vital in the production of this cash crop (Chatterjee, 2010). It has been found that cabbage needs nitrogen in the optimum amount, excessive N may result in formation of loose heads and internal decay. Alternatively, inadequate N amount results in non-formation of heads. Cabbage demand for P increases considerably at head formation stage, whereas, K deficiency can cause marginal necrosis and retards head quality. However, excessive K may result in head split (Khan *et al.*, 2002). Naturally reserved plant nutrients are not always readily available for plant uptake. Therefore, limited water and nutrient retention capacity in the soil is usually supplemented by fertiliser application. This results in the use of high amount of inputs (e.g. agro-chemicals) to ensure that production meets the nutritional demand for cabbage.

However, the intensive use of agro-chemicals has raised concerns for both the environment and society as it could have a major adverse contribution to climate change (Sinha *et al.*, 2010). Climate change is observed mostly where there has been a continuous usage of nitrogen fertilisers as residues leach and contaminate groundwater, as well as surface water in streams, consequently affecting human life (ANON, 2009). In addition to synthetic fertilisers, poor disposal of large quantities of both industrial and domestic wastes have become a major threat to the environment. This is due to the emission of greenhouse gases and bad odour or contamination of streams and ground water associated with such practices (Garg and Kaushik, 2003). Beside the health and environmental implications of using synthetic fertilisers, smallholder

farmers lack adequate resources (e.g. finances) and thus cannot afford to buy these fertilisers as they are very expensive.

Vermicompost is a two way practice of saving the environment by transforming waste materials into a valuable resource that can be used to supplement soil nutrients (ANON., 2009). Arancon *et al.*, (2005), described vermicopost as a product of interactions between earthworm and microorganisms by degradation of organic waste and the process is called vermicomposting. The vermicomposting process speeds-up the decomposition rates of organic matter, the physical and chemical properties of the material are altered, the process also reduces the C: N ratio, resulting in a rapid humidification process in which the unstable organic matter is completely oxidized and stabilized.

Benefits of applying vermicompost include high levels of nutrients; low levels of contaminants (Atiyeh *et al.*, 2000; Garg *et al.*, 2006; ANON, 2009) and increased surface area for colonization by microorganisms (Arancon *et al.*, 2005). Vermicompost contains readily available nutrients such as nitrates, phosphates, and exchangeable calcium and soluble potassium. The accumulating evidence shows that vermicompost has capability of influencing growth and productivity of plants (Rasool *et al.*, 2008).

Despite the positive effect that has been reported on vermicompost there is strong evidence that vermicompost does not always come out with positive results. Vermicompost could result in plant death or decrease growth depending on the variability of effects involved such as physical, chemical and biological properties of the vermicompost; incorporation system used; original feedstock; production process; age or earthworm species used. The effect may also depend on the plant species or variety involved (Lazcano and Dominguez, 2011).

Cabbage production can be expensive to many farmers in terms of fertilisation and pests/diseases management, especially for small-scale farmers. Lazcano and Dominguez (2011) have reported that a wide range of literature has been documented where vermicompost has been reported to be a better and cheap nutrient supplement over the synthetic fertilisers, and it was also proven to have significant effect on the growth of various types of plant species including agricultural crops. Vermicompost has proven to be a sustainable practice in crop production, Arancon (2007) has also emphasized ability of vermicompost to improve yield of crops like tomato. This study was therefore to investigate

the effect of vermicompost on the local variety of cabbage (i.e. *Brassica oleracea* var. Capitata). The findings will help encourage the use of this alternative especially by small-scale farmers. The consequent use of vermicompost will not only ensure good yields and profit but also environmental and soil quality sustainability.

The main objective was to investigate the influence of vermicompost on the growth and yield of cabbage (*Brassica oleracea* var. capitata), particularly Conquistador cultivar, which can be grown both in winter and summer conditions.

4.1 Specific objectives of the study

4.1.1 To determine the effect of vermicompost on the growth of cabbage.

4.1.2 To determine the effect of vermicompost on yield and quality of cabbage

2.2 Hypotheses

2.2.1 Vermicomposting does not have any effect on the growth of cabbage.

2.2.2 Vermicomposting does not influence yield and quality of cabbage.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The increasing population results in the production of large volumes of organic wastes. These are mostly from agricultural production (e.g. animal husbandry) and processing of kitchen wastes; plant litter, grass and other materials. These are currently considered as wastes to many people and may become pollutants to the environment and the atmosphere if not disposed correctly. Disposal of organic wastes can contaminate ground water, which can kill many lives including humans, as it is associated with hazardous odour and release of ammonia (Atiye *et al.*, 2000).

The issue around poor disposal of organic wastes has become a global concern; therefore, researchers have considered vermicomposting as a suitable method for maintaining a healthy environment and also a suitable technique to put the produced organic wastes to good use (Garg *et al.*, 2006). Vermicompost is a cost effective method that can be adopted by many farmers, particularly smallholders because it is easy and fast to prepare (Wang *et al.* (2010).

2.2 Vermicomposting

Vermicomposting is a practice of using worms (*Esenia foetida sp.*) to convert organic materials into a dark crumbly organic amendment, where worms feed on the organic wastes and produce undigested matter to be used for agricultural purpose such as soil fertility management, improvement of soil structure, management of weeds; pests and diseases (Bansal and Kapoor, 2000). During vermicomposting process, earthworms ingest the organic material and only a very small amount is synthesized in the body, whereas the rest is excreted as partially digested material and it is called worm casts (Loh *et al.*, 2005). Casting action involves physical/mechanical activities (e.g. grinding, mixing and substrate aeration) and the biochemical process which also involves microbial decomposition in the intestine of the earthworm (Ndegwa and Thompson, 2000; Loh *et al.*, 2005).

Overall vermicompost is an organic fertiliser that is proven to be highly nutritious and has the potential to modify the soil properties. Mineral nutrients such as nitrates, phosphates, and exchangeable calcium and soluble potassium present in vermicompost are readily available for plant uptake (Arancon *et al.*, 2002; Ndegwa and Thompson, 2001). Moreover, vermicompost is also known to promote growth, restore and improve the natural fertility affected by chemical fertilisers (Garg *et al.*, 2006). However, nutrient content of vermicompost depends on parent material (Lindsay *et al.*, 2005)

2.2.1 History and importance of Vermicomposting

Recycling of organic wastes has been practiced since early ages; however vermicomposting is a farming technology with improved aspects (Singh and Sharma, 2002). Vermicomposting was first recognised in Ontario, Canada in 1970 after being introduced by Darwin in 1881. It can be practiced domestically or industrially in marketing as an organic farming technology of waste management. This practice is an affordable, easier, fast and safe organic waste recycling technology that many farmers can adopt, and it does not impact the environment (Ndegwa and Thompson, 2000; Singh and Sharma, 2002).

2.2.2 Role of earthworms during vermicomposting process

Earthworms play an important role as the main drivers of the process in the vermicomposting technology (Datar *et al.*, 1997). According to Chaudhary *et al.* (2004) earthworm and microorganism interaction is most essential in the breakdown of organic matter and release of mineral nutrients into the soil. Hence, presence of earthworms during the vermicomposting process encourages high microbial activity and that influences biological activities in the soil. This accelerates plant germination, flowering, growth and yield since large microorganism population produce plant growth regulators and other materials involved in plant growth, which facilitates nutrients uptake (Garg *et al.*, 2006).

2.3 Vermicompost preparation

Vermicompost is produced through the interaction of earthworms with microorganisms that results in the degradation of organic material. In this process rate of decomposition of organic matter is accelerated causing the alteration of physical and chemical properties as well as lowering of C: N ratio of the material. This results in the oxidation and stabilization of the unstable organic matter (Arancon *et al.*, 2005).

The basic types of earthworm farming systems used by farmers are windrows, worm bin or beds and flow through reactors. Worm bins are worm housing containers that can be used for both home gardening and commercial agriculture. That can be a simple food storage container or an automated unit capable of processing large amounts of organic matter in a day. For effective processing, these bins must be dark with lids-drainage and well aerated underneath (Selden *et al.*, 2005).

2.4 Cabbage production and nutrients requirements

In order to obtain optimum plant growth, sufficient and unbiased nutrient quantities must be available in the soil. Although mineral nutrients are naturally available in the soil, they are generally not readily available for plant uptake or insufficient to satisfy the requirements of the cabbage crop (Olaniyi and Ojetayo, 2011). Consequently, the use of nutrient supplements has become fundamental to crop production (Olaniyi and Ojetayo, 2011). The type and amount of supplements depend largely on the soil type, quantity of mineral nutrients already in the soil as well as intended crop yield.

Cabbage may be an easy crop to grow but it requires intensive care, particularly in terms of major mineral nutrients (i.e. Nitrogen, Phosphorus, and Potassium) and irrigation. Nitrogen (N) is required in optimum amount in cabbage production because inadequate and excess amount of N in the soil may affect head formation. As a result loose head are produced or there will be internal decay or absence of head. Deficiency symptoms of potassium (K) in cabbage are identified by necrosis along leaf margins and retarded head quality, however excessive application may results in opening of heads; while

phosphorus demand results in increased manifold at head formation (Khan *et al.*, 2002).

Although fertiliser recommendation is determined through soil analyses for a particular field, the current fertiliser recommendation for cabbage production is 200 to 250 kg nitrogen per hectare, where N is applied in split application by broadcasting half to two-third just before planting. Side dressing is done in 2 to 3 weeks after transplanting and then again later in 3 weeks or it can be applied as a once off at 6 weeks. Top dressing should be done approximately 4 weeks after transplanting and again 4 weeks later if necessary (DAFF, 2010).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study site

A field experiment was conducted in 2012 at Syferkuil, University of Limpopo Experimental farm from July to October. The area's coordinates are 23° 51' 0" S longitudes and 29° 42' 0" E latitude; and it is located at an elevation of 1325m above sea level. Syferkuil farm is characterized by hot summers and mild temperatures in winter, with average day temperature estimated at 28°C to 30°C. It is dominated by a sandy loam textured Hutton soil form.

3.2 Soil sampling and analysis

A composite soil sample was taken at 0 to 15 cm depth before planting. Some of the soil was weighed after sampling and placed in an oven for 48 hours for soil moisture content determination. The remaining soil was air dried and sieved through a 2mm sieve prior to analysis. The following analysis was performed: pH in KCl at 1:1 soil: KCl ratio; Soil organic carbon was determined by Walkley Black modified method (IITA, 1982). Available phosphorus was determined by Bray 1 extract method (1995), particle size distribution by Hydrometer method and exchangeable bases using ammonium acetate method (IITA, 1982).

3.3 Experimental design

Cabbage seedlings ranging between 4 and 7 cm long of variety Conquistador were obtained from Martin Dale Seedling Company in Tzaneen. The study had seven treatments and was designed as a RCBD (randomized complete block design) with three replications. The seven treatments were made out of the three fertilisers, which were vermicompost [with N.P.K ratio 2:2:1 (2.5)], purchased from Talborne Organics Franchise group in Polokwane; vita grow (with N.P.K ratio 2:3:2 (16)) and chemical fertiliser [N.P.K 2:3:2 (22)]. The fertilisers were applied as singles at their recommended rates forming three treatments. The other three treatments were formed by combining two fertilisers at 50% recommended rate ie. Vermicompost and vitagrow; vitagrow and chemical fertiliser; and chemical fertiliser and vermicompost. The 7th treatment was planted without applying any fertiliser and that was the control.

Vermicompost was applied at 2500 kg ha⁻¹ (i.e. 25 kg N/ ha was applied); vita grow applied at 1500 kg ha⁻¹ carrying 68.6 kg N ha⁻¹ and the chemical fertiliser was also applied at 1500 kg ha⁻¹, which carried 93.5 kg N ha⁻¹. The fertilisers were therefore applied as compounds forming the other 3 treatments, with intergration of two fertilisers at 50% application rate of each fertiliser. The experiment plots measured with 5.4 m x 3.6 m plots of 6 rows each spaced at 0.6 m with in-row spacing 0.45 m, and that gives a plant density of 12 plants per row.

The seedlings were transplanted into the field at the end of July, where the experimental area was irrigated to field capacity a day before transplanting. Seedlings were pressed down firmly into the soil then lightly irrigated immediately after transplanting. Thereafter, irrigation was scheduled once a week, applying 250mm of irrigation water per irrigation using sprinkler irrigation system. The vermicompost used in the study was produced from dairy cattle manure and according to the recommendations on the package it was applied once at planting. The trial was monitored for pests and diseases and as necessary it was sprayed using non-selective chemical pesticide (i.e. Chloropyrifos – organophosphate insecticide with 500 g/L and is an anti-cholinesterase compound). The chemical was diluted as 5 ml into 10 L of water in a boom sprayer and full cover sprayed all the plants in the specified plots and the other treatments were evaluated as having no pesticide application. The crops were monitored for any constraints such as physiological disorders, pests or diseases. Weed management was carried out manually and frequently to ensure a weed free environment. The crop was ridged to ensure good drainage.

3.4.1 Data collection

Crops were evaluated weekly on physiological growth stages from four weeks after transplanting throughout to harvest. Three consecutive plants were selected from the two middle rows of each plot from which plant height and leaf number as well as chlorophyll content (using CCM-200 *plus* chlorophyll meter) were measured. The matured cabbage plants that have developed heads from the two middle rows in all plots were harvested and weighed, and graded as marketable (1kg or heavier) or non-marketable (less than 1kg).

Cabbage plants with formed heads were determined as fully developed cabbage crop.

3.4.2 Data analysis

Data collected were analysed using Statistix 9.0 software. Analysis of variance was performed and separation of means was done based on the Least significant difference (LSD) procedure at 5% probability level.

CHAPTER 4

4.1 RESULTS

4.1.1 Soil analysis results

The soil chemical and physical properties for the experimental site are given in Table 1. The soil was moderately acidic at pH = 6.62, and had sufficient available P (39.83 mg/kg). It was sandy loam with a very high sand percentage (99.37 %) which attributed to low organic carbon (0.45 %) and exchangeable K, Ca and Na.

Table 1. Soil chemical and physical properties

Soil parameters	Values
pH (KCl)	6.62
Organic carbon (%)	0.45
Available P (mg/kg)	39.83
Exchangeable K (c mol/ kg)	0.38
Exchangeable Na (c mol/ kg)	0.50
Exchangeable Ca (c mol/ kg)	1.47
Soil moisture content	2.61
Sand (%)	99.37
Silt (%)	0.11
Clay (%)	0.52

4.1.2 Growth parameters of cabbage

Plant height, leaf chlorophyll content and number of leaves are presented in Table 2. Comparison of the fertilisers and their combinations at 99% confidence interval showed that chemical fertiliser (CF) treated plants had more ($P < 0.01$) chlorophyll content than vitagrow (VG) and vermicompost (VC), including the combinations and control. The content varied from 55.8 to 80.6 nmol/mg and CF had 80.6 nmol /mg. Vermicompost and the control did not differ significantly in chlorophyll content. Furthermore, Vitagrow alone had similar effect ($P < 0.01$)

as combinations of VC with CF and VG (i.e. VC+VG and VC+CF) and had relatively higher chlorophyll content than VC.

Statistical analysis for the number of plants differentiated at 95% confidence interval indicates that there was no significant ($P < 0.05$) difference between the VC, CF and VG including the combinations (VC+VG, CF+VC and VG+CF) and the control. Similar effect was observed on number of leaves as the three fertilisers and the combinations varied from 17.3 and 17.7 (Table 2) from the seedling stage until harvest.

The fertiliser effect tested on cabbage crop showed plant height values ranging from 15.4 to 22.8 cm. Variation of plant height means at 99% confidence interval showed that plants treated with CF were significantly taller than plants in VC and VG and the combinations, including the control. The fertilisers tested were superior to the control.

Table 2. The effect of different fertiliser application on physiological growth of cabbage (measured from seedling to harvest)

Treatments	Chlorophyll (nmol /mg)	No of leaves plant ⁻¹	Plant height cm
VC+VG	60.9 bc	17.7 a	17.8 cd
VG+CF	69.0 b	17.3 a	20.0 b
CF	80.6 a	17.3 a	22.8 a
CF+VC	63.5 bc	17.6 a	18.3 bcd
VC	58.6 c	17.6 a	16.1 de
VG	63.1 bc	17.6 a	18.6 bc
CONTROL	55.8 c	17.6 a	15.4 e
P value	0.0008*	0.7047 ^{ns}	0.0000*
CV %	11.87	2.57	8.94
RE	5.01	163.28	11.60
Std error of a mean	3.43	0.20	0.74

Similar letters in the one column express the non-significance of the means. (*) = significantly different ($P \leq 0.05$), CV = Coefficient of variation, RE = relative efficiency, VC+VG= vermicompost with vita grow, chemical fertiliser with vitagrow, CF+VG= chemical fertiliser with vitagrow, CF= chemical fertiliser, VC+CF= vermicompost with chemical fertiliser, VC= vermicompost, VG= vitagrow, CONTROL= no fertiliser applied.

4.1.3 Head yield and yield parameters of cabbage

Yield attributes of the experimented cabbage are given in Table 3 and 4. Results for number of plants at harvest showed non-significance differences ($P < 0.05\%$) with the means varying from 22.0 to 24.0. Vermicompost and control attained 22 plants which was similar to the control, while CF and its combinations (CF+VC and CF+VG) had 23.7, 23.3 and 24.0 higher number of plants at harvest respectively. Control had fewer plants with fully formed heads as compared to CF, VC and VG, as well as the combinations (Table 3), while CF+VC had the highest higher number of fully formed heads at 19.3. The control had the least number at 11.3 per plot. Chemical fertiliser attained equal number of fully formed heads as VC+VG. Number of marketable heads

showed lowest percentage in control than in all other treatments. All the fertilisers and their combinations showed no significant difference in number of marketable heads. The control attained lowest average marketable head weight (1.310 kg) however there was no significant difference between the control and the fertilisers. Average marketable head weight ranged between 1.310 to 1.613 kg and the highest was recorded in CF although results showed no significant differences between treatments. Number of marketable heads (graded as percentage of fully formed heads) ranged from 34.9 to 84.5 %. Although marketable heads were not significantly affected by any of the treatments, VC+VG combination produced the highest percentage followed by CF then CF+VC (84.46; 82.62 and 79.23%, respectively).

Vermicompost had the lowest marketable heads as percentage of total plants although there was not significant ($P < 0.05$) difference from that of VG and CF or combinations, but higher than the control. Combinations of VC (VC+VG=63.10 and CF+VC= 64.27) attained higher marketable heads as percentage of total plants than VC however there was no significant difference. Vermicompost, vitagrow and chemical fertiliser showed non-significant effect on the weight of marketable heads per hectare, including their combinations, although control had significantly lower weight of marketable heads (2829 kg ha^{-1}). The highest weight of marketable head was recorded for CF at 12740 kg ha^{-1} followed by CF+VC as well as VC+VG, which had 12020 and 11060 kg ha^{-1} respectively. Average of marketable head (1.0 kg or higher) weight ranged between 1.31 kg and 1.61 kg and CF produced the highest. Economic value of the produced cabbage (computed from the total number of cabbages produced) showed that only few were marketable. Thus, most of the cabbages produced were non marketable from the size perspective.

Mean fresh weight in Table 4 recorded non-significance values ranging between 1.03kg and 1.69kg, where VG had the highest weight. Vermicompost and its combinations had lower fresh head weight than CF and VG however; the combination CF+VG had lower fresh weight (1.13kg) than VC+VG and CF+VC (1.46kg and 1.42kg, respectively). Control showed great values compared to VC (1.03kg)

Table 3. Effect of different fertiliser applications on yield and various yield components of cabbage

Treatments	No of plants/plot at harvest	No of fully formed heads	No of marketable heads	Marketable heads as % of fully formed heads (%)	Average marketable head weight (kg)	Marketable heads as % of total plants	Weight of marketable heads/ha	Variance with the control
VC+VG	23.000 ab	17.0 ab	14.7 a	84.5	1.453 a	63.10 a	11060 ab	0.2400
CF+VG	24.000 a	16.3 ab	10.3 ab	61.2	1.387 a	43.06ab	7356 ab	-0.0900
CF	23.667 ab	17.0 ab	14.7 a	82.6	1.613 a	61.53 a	12740 a	0.2800
CF+VC	23.333 ab	19.3 a	15.0 a	79.2	1.570 a	64.27 a	12020 a	0.2000
VC	22.000 b	15.0 ab	8.0 ab	52.1	1.350 a	35.91 ab	5453 ab	-0.1867
VG	23.333 ab	12.7 ab	9.0 ab	61.9	1.513 a	39.39 ab	8282 ab	0.4767
CONTROL	22.333 ab	11.3 b	4.3 b	34.9	1.310 a	19.93 b	2829 b	
P value	0.3049 ^{ns}	0.2446 ^{ns}	0.2 ^{ns}	0.3 ^{ns}	0.804 ^{ns}	0.2202 ^{ns}	0.2508 ^{ns}	
CV %	4.58	24.7	49.5	40.1	19.410	48.72	59.88	
Std error of a mean	0.6108	2.2	3.1	15.0	0.163	13.15	2950	

Similar letters in a column express the non-significance of the means in the same column. (^{ns}) =not significant (P< 0.05), CV = Coefficient of variation, RE = relative efficiency, VC+VG= vermicompost with vita grow, chemical fertiliser with vitagrow, CF+VG= chemical fertiliser with vitagrow, CF= chemical fertiliser, VC+CF= vermicompost with chemical fertiliser, VC= vermicompost, VG= vitagrow, CONTROL= no fertiliser applied.

Table 4. Effect of different fertiliser applications of the fresh weight of cabbage (kg)

Treatments	Mean fresh head weight (kg)	Standard deviation of average weight (kg)	Total head weight (ha)
VC+VG	1.46 a	0.33	239000
CF+VG	1.13 a	0.22	174000
CF	1.50 a	0.34	247000
CF+VC	1.42 a	0.37	240333
VC	1.03 a	0.04	142333
VG	1.69 a	0.43	17167
Control	1.22 a	0.49	88000
P value	0.27 ^{ns}		949 ^{ns}
CV %	24.69		47.10
STD error	0.19		50592

Similar letters in the one column express the non-significance of the means in the same column. (^{ns}) = not significantly different ($P < 0.05$), CV = Coefficient of variation, RE = relative efficiency, SD= Standard deviation, VC+VG= vermicompost with vita grow, chemical fertiliser with vitagrow, CF+VG= chemical fertiliser with vitagrow, CF= chemical fertiliser, VC+CF= vermicompost with chemical fertiliser, VC= vermicompost, VG= vitagrow, CONTROL= no fertiliser applied

4.2 DISCUSSION

4.2.1 Initial soil fertility status

Very high percentage of sand with corresponding high porosity, low water holding capacity and low exchangeable bases shows that the soil at the trial was infertile. Nitrogen, phosphorus and potassium are needed for head formation in cabbage. Thus, the low initial levels of N and K in the soil may have attributed to generally low yield observed across treatments. This may have been significant under organic fertiliser treatments since they are characterised as slow releasers. Furthermore, inadequate soil moisture may have hindered nutrient uptake and consequently crop growth and yield. This is because adequate moisture in the soil enhances nutrient uptake by plants (Semuli, 2005). The soil had moderately acidic pH and thus sufficient available P. The initial fertility status of the soil maybe a result of previous management as the site is commonly used for crop production research. About 200 to 250 kg/ha of nitrogen is required for cabbage production (DAFF, 2010). In the current study, nitrogen was applied at 25, 68.6 and 93.5 kg/ha for VC, VG and CF, respectively, following the recommended application rates. It is evident that the applied rates of the fertilisers resulted in low application of N, relative to recommendations, and this could explain the relatively poor performance of the crop. Hasan and Solaiman (2012) indicated that cabbage responds highly to N and moderately to P.

4.2.2 Initial growth vigour

4.2.2.1 Chlorophyll

Chlorophyll plays a major role in the metabolic processes of plants and thus contributes greatly to crop growth and yield. Sole application of chemical fertiliser as well its mixtures with VG and VC contributed positively to chlorophyll content. This is consistent with results recorded by Chatterjee (2010). The observed effect of CF and its combination might be due to the direct impact of inorganic fertilisers particularly nitrogen element. High N (93.5 kg/ha) was applied for this treatment. Nitrogen is an essential part of the chlorophyll

molecule, hence essential for its formation. The supply and availability of this mineral element to the crop is faster when an inorganic fertiliser is used. This is contrary to vermicompost treatments which had low N (25 kg/ha). As a result these treatments showed low chlorophyll content.

4.2.2.2 Number of leaves plant⁻¹

The number of leaves plant⁻¹ is considered as an important parameter considering the highest performance of cabbage yield. Well-developed leaves are needed for good head development. Moreover, tight packed and unexpanded leaves support the head and result in a desirable firm head (Hasan and Solaiman (2012)). All fertiliser treatments did not affect the number of leaves per plant. The constant number of leaves per plant through most of the growth stage strongly suggests that this is a genetic trait associated with the Conquistador variety. This low number of leaves could explain the smaller size of the Conquistador variety. However, according to Andaloro *et al.*, (1983) low number of leaves determines the weakness of the crop to pests and diseases and this was evidenced during the trial.

4.2.2.3 Plant height

Plant height was influenced by fertiliser type (Table 2). This indicates positive growth response among the treatments that might have been influenced by rapid performance on growth characters. However, chemical fertiliser and its mixtures significantly affected plant height compared to other treatments. A similar response of cabbage plant height to fertilisers was recorded by Hasan and Solaiman (2012). Hasan and Solaiman (2012) attributed this positive response to high N. This element is rapidly released when chemical fertiliser is used and thus greatly contributes to initial vigorous growth, this is supported by Hasan and Solaiman (2012) conducted an experiment comparing efficacy of organic and inorganic fertiliser and their results indicated that CF perform better than organic fertiliser. The poor performance of vermicompost compared to the chemical fertiliser maybe due to the parent material sources used in the production as this affects the nutrient content of the compost.

Differences in growth responses may be partially due to the nutrient composition of the fertilisers or the fact that organic fertilisers are slow releasers of nutrients. Arancon *et al.* (2005) indicated that there is only little documentation on increased crop growth in soils amended with vermicompost.

However, these current results might be affected by many factors. Moisture requirements in cabbage are critical at the young stage; therefore, water supply should be constant for a good vegetative growth before head formation. In this study, sprinkler irrigation system was used and this study was conducted during windy season (spring); most of the irrigation water could have drifted away during irrigation and not penetrates the root zone. Thus, the plants might have suffered moisture stress as most were stunted. Plants in the control plots had stunted growth and this may be due the soil characteristics. Proper irrigation scheduling is necessary and the schedules need to be followed until cabbage heads are fully formed and firm. In the case of the current experiment, the irrigation schedule was not properly followed and this might be amongst the factors that affected growth and then yield. Many plants at the extremes of the experiment had poor growth and most of them failed to produce fully formed heads due to under irrigation. However, plants in the control did not have any fertiliser application therefore; growth might have been affected by insufficient nutrient availability in the soil.

4.2.3 Cabbage head development at maturity: Size and quality

It is evident that most of the transplanted seedlings survived the growth period through to maturity. Although the trial could not produce fully formed heads in some plots of different treatments and even when cabbage heads were formed, they were not of good quality or market size. Produced cabbage under chemical fertiliser treatments and its combinations showed good quality and market size, the cabbages were heavy with wrapper leaves firmly attached. Thus treatments did not affect stand establishment. This may be attributed to many factors. Fertilisers need water to dissolve into available form, therefore, according to the observed results irrigation water have not been sufficient enough to dissolve the fertilisers. The size of the cabbage was affected by insufficient water supply, which therefore affected quality. For example, nutrients might have been

washed away or leached beyond the root zone because the soil was sandy. Alternatively, it is also possible that the plants utilised most of the nutrients during vegetative growth period because cabbage has high nutrition demand (Olaniyi and Ojetayo, 2011) or the applied nutrients were not sufficient enough. The results may have been affected by the response of the plant to vermicompost, because according to Lazcano and Dominguez (2011), plants respond differently to vermicompost and important differences in nutrient uptake capacity is determined by plant genotype.

Fresh weight is a key parameter and cabbage head is considered as an important yield component of the crop. Clearly the number of plants at harvest does not determine number of fully formed heads and the number of fully formed heads does not necessarily determine weight or market value of cabbage. Therefore, the aspect of low head weight needs to be improved to increase economic value of cabbage. Moreover, the size of the cabbage head is very essential in fresh market sales and there are several factors that can influence cabbage head size. Factors such as higher plant populations might have influenced the results on the yield attributes in the present study. Total weight in this study was not positively affected by the treatments which might be due to the least availability of nutrients at growth and development (Khan *et al.*, 2002). Khan *et al.* (2002) has further observed increase in marketable yield as N rate was increased, thus the amount of N that was available in the soil might have compromised the results on total weight.

Bagrada bug (*Bagrada hilaris*) and cutworm were among the pests that were observed to have infested in the field. Bagrada bug is a small insect that affects the head of cabbage and results in multi-headed cabbage, thus, production of fully formed heads was affected and consequently economic yield. Infestation of bagrada bug resulted in stunted growth with leaves becoming chlorotic and production of multiple unmarketable heads or heads were not produced at all ('blind heads') (Palumbo, 2010). The consequent reduction in yield and development of low grade cabbage is supported by Adolaro *et al.* (1983) who indicated that, damaged wrapper leaves of cabbage even if slightly injured could reduce grade and further wrote that, an economic loss in cabbage

marketability is reflected either on weight or grade. Although, low grade cabbage might be unmarketable but the cabbage can still be used for home consumption. Alternatively, the smallholder farmer could still sell the produce to small market entrepreneurs (hawkers) or neighbours to generate income.

Sustainable agriculture can be defined as the type of farming method that involves resource conservation and safety of the environment and human health. Therefore the use of organic amendments is one of the main features of concern on issues such as food quality, environmental safety and soil conservation. This has led to an introduction of organic fertilisers such as vermicompost as they do not compromise consumer needs (Tilman *et al.*, 2002).

In the current study treatments were arranged in such a way that the use of chemical fertilisers is reduced. Organic fertilisers are produced from plant residues which are biological resources and readily available to smallholder farmers and they benefit the environment from the production stage (ANON, 2009).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Vermicompost did not have pronounced effect on growth and yield as the objective stated. The current results conclude that synthetic fertilisers perform better than the organic manure. Recent studies suggest that use of vermicompost has great potential, whereas results in this study may raise doubts. Biological property of vermicompost is the main factor in order to stimulate plant growth, alternatively plant species used or cultivation condition. Improved chlorophyll content and plant height on cabbage indicates that vermicompost could have attributed to growth but could not perform well as compared to chemical fertiliser and vitagrow. This may therefore support the argument that vermicompost is effective as a horticultural media not when directly applied in the field. However the results do not necessarily mean that organic fertilisers are not suitable to be used in agricultural field practices. Generally, the hypotheses was correct, vermicompost at the level tested, did not have effect on neither growth nor yield of cabbage.

However, farmers can still use vermicompost as soil amendment in the field, provided it is produced from the organic material rich in nutrients, specifically with high N. Alternatively, the application rate can be improved because in the present study, it was recommended that it should be applied once at planting. Whereas, the results suggest that with the applied rate N was not sufficient enough to improve growth and yield of cabbage.

Future studies should utilise well regulated irrigation and include basic economic analysis, especially the relative costs of nitrogen and related returns. Scoring for disease and insect pest damage will also enhance the evaluation of cabbage head quality.

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