PERFORMANCE OF RAPE (*Brassica napus*) GROWN UNDER ORGANIC FARMING COMPARED TO CONVENTIONAL PRACTICES.

BY

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DECLARATION

I, Muleya Mukonde Patrick hereby declare that the work presented in this thesis was my own and has never been submitted for a degree at this or any other University.

Signed: ……………………………………………………………….

Date: ………………………………………………………………..

APPROVAL

This thesis of Mr. MULEYA MUKONDE PATRICK is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy (Crop Science) by the University of Zambia.

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ABSTRACT

This study was carried out during the 2008/09 season under irrigated conditions. It was conducted at the University of Zambia (UNZA), School of Agricultural Sciences Field Station. The objective of the study was to determine the yield response of selected varieties of a leafy vegetable, Rape *(Brassica napus)* grown under organic and conventional practices and ultimately provide evidence of the potential of organic farming. The specific objective of the study was to evaluate the suitability of organic manure as a source of nutrient nitrogen for plant growth in organic production system compared to conventional system Three varieties (English giant, Nanga and Prior), three nitrogen levels (10, 20 and 50 Kg N/ha) from D-compound and three organic sources (undecomposed, partially decomposed and fully decomposed composts) under the two farming systems (conventional and organic) were used as main and sub plots respectively. A Strip-Split Plot Design was used. The yield parameters measured were number of leaves per plant, leaf width, leaf area index (LAI) and leaf yield. The nitrogen content of leaves and in the soil after harvesting were also determined. The results indicated that applied nitrogen level had a significant effect ($P<0.05$) on all the yield parameters measured with the highest results obtained under the rate of 50 Kg N/ha. Varieties were different for number of leaves per plant. The variety Nanga had the highest (20) number of leaves per plant while the variety English Giant had the lowest (13) number of leaves. The plants grown under conventional farming gave a significantly ($P< 0.05$) higher number of leaves (19) per plant compared to (16) for those under organic farming. Nitrogen levels were also significantly ($P<0.05$) different for leaf width. The smallest leaves were under the level of 20 Kg N/ha (7 cm) while the other two nitrogen levels the leaf widths were not significantly different. The farming methods were different for leaf width with the conventional producing wider leaves (8.85 cm) than those from organic farming (7.59 cm). The nitrogen levels were also significantly different ($P< 0.05$) for leaf area index (LAI). The highest LAI of 55.5 was observed under the 50 Kg N/ha while the other two were not significantly different. The varieties were not significantly different for LAI. However, significant differences for LAI were observed between conventional and organic farming. Conventional farming gave a higher LAI of 50 compared to 28.6 for organic farming. Relative higher leaf yields were obtained under 50 Kg N/ha treatment and under the variety English Giant, but there were no significant differences observed among the nitrogen levels and varieties for leaf yield. Similarly, no significant differences were observed between conventional and organic farming for leaf yield. Farming methods were significantly different for soil N with organic (0.30%) producing higher than conventional farming (0.24%). No significant differences were observed among nitrogen levels, variety and farming methods for plant tissue N. The average leaf yield of 1.6 tons/ha for the conventional and 1.2

tons/ha for the organic farming respectively were not significantly different ($P < 0.05$) thereby making organic farming a viable alternative to conventional practices.

DEDICATION

To my parents and siblings, both nuclear and extended who have lived to see me make yet another contribution to science.

Brothers Kennedy and Owen for the love and support.

Beloved Mama and the lovely Trench Kids for upholding the ‘never give up’ slogan.

I will never manage to thank you enough, you the custodians of the Trench Farms!

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I.0 INTRODUCTION

Rape (*Brassica napus*) is a leafy vegetable mainly planted for the use of its leaves as relish. It belongs to the Brassicae family. Vegetables play a very big role in the human nutrition especially as sources of vitamins such as vitamin C, minerals and dietary fiber (Craig and Beck, 1999; Wargovich, 2000). All over the world, vegetables are used either as a whole meal or as a complement to the main meal (Craig and Beck, 1999). In Zambia, vegetables constitute an important component in the diet of people. Rape is a very important cash crop and relish crop grown by a wide range of farmers in Zambia. It ranks second from Tomato among small-scale farmers and backyard gardeners (Mingochi and Luchen, 2000). Most of the rape produced in Zambia is for local domestic fresh market; hence production and sale statistics are not readily available (AVRDC-ARP, 1997).

Rape can be grown throughout the year, but its growing peak is during the cool dry season. Production declines in the hot and dry period from August to October and in hot and wet period from November to March (Mingochi and Luchen, 2000). Scarcity becomes more pronounced in the hot humid months of November to April due to the high incidence of disease and pests. The most important disease and pests of rape are Black rot (*Xanthomonas campestris*) during the rainy season, Diamond back moth (*Plutella xylostella*) in the hot dry season and Aphids (*Brevicoryne brasssicae*) through out the year. Other pests observed on brassicas in the field include cutworms (*Agrotis spp*.) (Mukuka *et.al*. 2002).

Vegetable production under traditional practices is characterized by low yields due to a number of factors among which are low soil fertility. Soil nitrogen particularly is the most limiting nutrient. To address this challenge, soil amendment through application of fertilizers, especially the inorganic type, is generally recommended. However, inorganic fertilizers are expensive for most farmers that grow vegetables, hence the problem of inaccessibility and inputs therefore generally applied in low rates. The use of organic fertilizers presents itself as an alternative to inorganic fertilizers; unfortunately very little work on how much of the organic fertilizer should be applied as a substitute to inorganic fertilizer has so far been done. There is a need to elucidate production of vegetables under organic farming.

Organic farming is a holistic production management system that avoids the use of synthetic fertilizers, pesticides, antibiotics, genetically modified organisms and minimizes pollution of soil and water offering an alternative food system (Scialabba, 2007). Organic farming has numerous advantages attending to its application which include: On average 30% less fossil energy use, conserve more water in the soil, induces less soil erosion, maintain soil quality and conserves more biological resources than conventional farming (Pimentel, 2005).

- Therefore, this study was initiated to provide evidence of the potential of organic farming.

- The study also intended to evaluate the suitability of organic manure as a source of nutrient nitrogen for plant growth in organic production system compared to conventional system.

- Nutrient nitrogen applied as organic manure supports plant growth and development and presents itself as a viable alternative option for vegetable production.

2.0 LITERATURE REVIEW

Yield is the most important component of any farming system. It has a significant bearing towards household, national and global food security. Resources or inputs injected into a farming system to realize the yield thereof including issues pertaining to accessibility of the said inputs are cardinal as they can otherwise seriously affect the yield (Mueller, 2005). Most studies have attributed the yield response of rape to some physical inputs such as light, temperature, nutrients and water supply (Thurling, 1974). It is also reported that variation in dry matter accumulation by different varieties may be related to Leaf Area (LA), Leaf Area Index (LAI) and other growth parameters. Leaf area here will refer to the upper surface area of leaves. Total leaf area is a product of leaf number, size and the net difference between additions of leaves and death of leaves at any given time.

Several environmental factors affect leaf area (Wilson, 2004). Size of leaves has been reported to be largely determined by the nutritional status of the soil in which the plant grows (Pushparajah and Chew, 1994, Wilson *et.al*., 2002, Reid, 2002). Leaf area index (LAI) is defined as the average leaf per unit of land. It has been seen to respond to changes in total leaves per plant and number of nodes per plant. LAI increases with increasing density (Wilson, 2004, Zyskowski *et.al.* 2004). Disease and pest management has also been reported to have important effects on LAI. Yield losses are likely to ensue when LAI values drop below critical levels because of disease and pest damage (Butler and O'Neil, 2007).

Nitrogen is an important plant nutrient. Nitrogen increases total leaf area per plant and per unit area by increasing number and size of leaves (Sompongse and Pushparajah, 1994). It is also an integral part of chlorophyll, which is the primary absorber of light energy needed for photosynthesis. An adequate supply of nitrogen is associated with vigorous vegetative growth and the green color (Sompongse and Pushparajah, 1994). An imbalance of nitrogen or an excess of this nutrient in relation to other nutrients such as phosphorus and potassium can prolong the growing period and delay crop maturity (Schomberg and Weaver, 1990; Vanlauwe *et.al.,* 1999; Marschner, 1990). Nutrient nitrogen (N) can be obtained from either conventional or organic sources for utilization in plant production (Bacon, 1995; Lee and Kader, 2000).

The nutrient nitrogen (N) from organic sources can be produced by composting plant residues, poultry manure and cow dung and from the utilization of plant-legume crop rotations. The full decomposition of poultry (chicken) manure requires incubation period of 26 weeks, at an average temperature of 23 ^{0}C in a non-leached condition thereby giving a mineralization percentage or efficiency coefficient of 67% (Bacon, 1995). Poultry manure is not only higher in total N but will provide more N upon decomposition in the soil than will other, more stable wastes (Bacon, 1995; Lee and Kader, 2000).

2.1 Rape Yield

The Brassicas have diverse growth types and encompass various species including specific hybrids. Turnip (*Brassica rapa*.L.) produce primarily root biomass. Kale (*Brassica oleracea* L.) and Rape (*Brassica napus* L.) produce mainly leaf and stem while Pasja (a fast growing early maturing Turnip- Chinese cabbage hybrid) produce much leaf but little stem or root (Wilson, 2004). Most of the cruciferous crop plants originated in temperate countries and grow best in cool moist climates and at higher altitudes in the tropics. They are not readily suited to the low humid tropics.

The best vegetables production in the tropics requires ideal conditions such as an altitude of 6200ft, with a mean maximum temperature of 23.9 ^{0}C and a mean minimum temperature of 10 ^{0}C. The ideal soil for brassicas is a rich sandy loam (Purseglove, 1974). According to Mingochi *et. al*., 2000, rape takes on average 42 days to reach maturity with an average leaf harvesting duration of 48 days. It has an average yield potential of 22 tons/ha especially in Agro-ecological region II of Zambia due to its favorable combination of good climate and soil types. He reported that the actual average yield of rape falls below 10 tons/ha and has remained static for some time despite the many technological advances made in agriculture. The wide gap between the actual and potential yield is due to many factors which include low or no fertilizer application, improper selection of suitable cultivars and inappropriate cultural practices under farmers' condition. Fertilizer costs are very high, such that most small scale farmers cannot afford to buy them with their financial resources (Mingochi *et. al*., 2000).

2.2 Cultivar Characteristics

A cultivar of the same species may yield better than another under similar conditions due to its inherent genetic attributes (Chaudhary, 2007; Harvey, 1939). It has been reported that there are considerable differences between and within plant species in their ability to take up mineral nutrients from the soil (Levang-Brilz, 2003; Marschner, 1990; Arnon, 1972 and Harvey, 1939). Higher yielding cultivars tend to give higher yields with no added fertilizer than poor yielders. This may be due to the efficiency with which cultivars use the limited soil available nutrients (Shenoy, 2005; Kumwenda *et. al*., 1996).

It has been stated that nutrient uptake from the soil is a function of the plant's root volume and the nutrient concentration in the soil solution as well as the soil- root contact effect (Hurd, 1968; Srivastava, 1970; Mengel and Kirkby, 1987; Hoffland, 1990). Studies have shown that temperature, cultivar and tillage practices also affect nutrient uptake from the soil (Hoyt *et. al*., 2006; Tisdale *et. al*., 1985). Another attribute which renders one cultivar superior to others under similar conditions, is its ability to optimize the use of absorbed nutrients in meeting its metabolic functions such as dry matter accumulation. The ability of the plant to optimize the use of nutrients is enhanced by its photosynthetic efficiency under sub-optimal conditions (Waala, 2009; Blankinship, 1999; Chan-Seng *et. al*., 1990).

2.3 Plant Leaf size

There is a genetically determined upper limit to the size of a leaf for any crop species when growing conditions are favorable. Ontogeny and environmental factors like temperature, soil moisture, and nutrient supply control the leaf size (Dewitte, 2007; Cordell, 2000; Kirkby *et. al*., 1982). Nitrogen nutrition increases the size and duration of the canopy which leads to increased dry matter accumulation (Arduini, 2006; Hay and Walker, 1989). Nitrogen affects the rate of leaf expansion and its final size (Trapani, 1999; Milthorpe and Moorby, 1979).

Canopy development is simulated by calculating the leaf area of an average plant each day, and accumulating total leaf area for all plants in a population. Leaf area calculations account for the production and loss of successive leaves. Daily biomass production is the product of the amount of radiation intercepted by the canopy and critical radiation use efficiency (Neto, 2006; Wilson, 2004). New biomass is distributed to leaf, stem and root fractions using empirical partitioning coefficients. The model accurately predicts canopy development, biomass production and biomass distribution of different basic types.

Expansion of each leaf to its full size is defined by a dimensionless "shape" factor which is 0.004 for Rape and Kale (Zyskowski *et. al*., 2004, Reid, 2002 and Reid *et. al*., 2002). In cereals, the leaf area is the product of the length and width multiplied by 0.75. The factor 0.75 is used because it is assumed that if a cereal is placed on a rectangle the same length as the leaf, the leaf will occupy three quarters of the rectangle (Liang, 2009; Kemp, 1960). Similarly leaf area in tobacco can be determined by measuring leaf length and width (widest portion) and multiplying by a factor of 0.6235. This factor is used on the assumption that a tobacco leaf when superimposed on a rectangle of same length will occupy about two thirds of the rectangle (Remison, 2008; Hammer, 1980).

It has been reported that there was an increase of canopy height and leaf spread when N fertilizer was increased from 50 Kg/ha to 100 Kg/ha (Newman, 2002; Milthorpe and Moorby, 1979).

Mineral deficiencies of Phosphorus (P) and Potassium (K) reduce leaf size even when N supply is adequate (Marschner, 1990; Stoskopf, 1981, Hay and Walker, 1989). When P is deficient in the soil, plant growth is retarded. The growth of shoots and roots is restricted. The leaves are small and together with the stems become purplish, thus reducing the photosynthetic capacity of the crop. Purpling is enhanced by the formation of anthocyanin (Marschner, 1990). K is needed for cell division, growth and along with Calcium (Ca), it is a neutralizing agent for organic acids. It is needed for osmo-regulation and for the efficient synthesis of carbohydrates. It plays a role in the formation of sugars and starch as well as the transportation of these products. When K is deficient, shoot and root growth is restricted (Marschner, 1990; Mengel and Kirkby, 1987).

2.4 Leaf Concentration of N, P and K.

For many years, the analysis of plant materials to evaluate and help in explaining some crop responses to some fertilizer application rates under some conditions have been done. The composition of elements in the plant tissue is now accepted as a more sensitive indicator of crop response to environmental changes (Sinclair, 1997; Melsted *et. al*., 1969). In evaluating plant tissue concentrations or contents of some key elements of interest, it should be realized that several variables are usually acting on the results that may be observed. These variables may be unknown or cannot be definitely evaluated by the interpreter. Some of these variables are crop cultivar, soil type, season, crop management and fertilizer treatment (Kozai, 1994; Martin- Prevel *et. al*., 1984).

In most cases, the objective of plant tissue analyses is to assess a soil or fertilizer and crop management practices. It has also been confirmed that even if treatments may be the same, if the soil type, season and variety are different, the N, P and K concentrations of a plant tissue will differ between locations and within varieties (Leith, 2008; Melsted *et.al*., 1969). Kamprath *et. al*., 1982 reported that the content of N in leaves has been found to be affected by sandy soils. It has also been observed that under less precipitation, more N was recovered by the leaves and yet under high precipitation less N was recovered due to loss of N by leaching. The N concentration in leaves increased with increasing fertilizer rates applied. The study also showed that N additions should take into account soil reserves of N as they contribute to uptake during the growing season (Leith, 2008; Kamprath *et. al*., 1982).

2.5 Nitrogen Requirements and Fertilizer application.

Nitrogen is taken by plants primarily as nitrate-N (NO_3^--N) or ammonium-N (NH_4^+-N) ions. The actual process of N uptake by plants requires movement of ionic species of N to root surfaces for absorption. Most N movement occurs as NO_3^--N in the convective flow of soil water to plant roots in response to the transpiration pulls in the above ground portion of the crop (Marschner, 1990). In addition to the moisture factor, rate of nitrate uptake is controlled by its concentration in the soil solution and plant metabolism

(Waterer, 1993; Olsen and Kurtz, 1982). The uptake of both N forms is reported to be temperature dependent; low temperatures depress the uptake (Kim, 2007; Pedersen, 2004; Zsoldos, 1972; Clarkson and Warner, 1979).

Nitrogen uptake is also affected by the soil pH. Ammonium-N uptake takes place best in a neutral medium and it is depressed as pH falls, but for the nitrate-N, a more rapid uptake occurs at low pH values. The two N forms are absorbed at equal rates at pH of 6.8 (Wang, 2009; Rao and Rains, 1976). It has also been stated that the uptake of nitrate-N was considerably higher than that of ammonium-N at pH 4.0 (Pal'ove-Balang, 2007; Michael *et. al*., 1965).

The soil root system must supply N in the quantities needed by the crop to achieve high crop productivity. High utilization must also be ensured by optimizing the fertilizer N rate, timing and application methods. The application of an optimal amount of N is considered the most important single N management factor affecting crop productivity and efficiency (Hirel, 2007; Liu, 1991).

Information from analysis of both soil and plant tissue is very important in determining N fertilizer needs of crops. The N requirement can be measured by investigating crop yields with different levels of N fertilization and /or by determining the correlation between tissue N concentration and performance yield (Liu, 1991). The critical N level or concentration in the tissue and/ or in the soil can be used as a tool for determining the N requirement of crops. Critical level or concentration is defined as the level of N in the plant or soil which divides the zone of deficiency from the zone of adequacy (Henke, 2008; Liu, 1991). This critical N concentration is generally determined by growing crops which are well supplied with nutrients other than N and then adding N in increments until an adequate or excessive level is reached. The most meaningful definition of critical N concentration for efficient growers is the level of N below which crop yield, quality or performance is unsatisfactory (Liu, 1991; Marschner, 1990).

As nitrogen losses are usually inevitable and N mineralization is often less than crop needs, nitrogen fertilizers are necessary to meet the nitrogen requirement of intensively grown arable crops and field vegetables (Henke, 2008; Bacon, 1995). The nitrogen requirement ranges from about 40 Kg N/ha per year for crops such as Radish (*Raphanus sativus* L.) to about 300 Kg N/ha per year for cabbage (*Brassica oleracea* L.). Fixed rate fertilizer recommendation, which is the simplest type, consists of recommending a fixed nitrogen rate for a crop in all situations, regardless of soil type and field histories. Advantages of this method are its simplicity and that there are no costs involved for soil analysis (Marschner, 1990; Bacon, 1995).

In Zambia, the basal fertilizer recommendation for Rape is 10 x 50Kg bags or 500 Kg/ha D- Compound fertilizer which has an N, P and K grade of 10:20:10. This translates into 50 Kg N/ha for basal dressing. For top dressing it is recommended to apply 70 Kg N/ha achievable when 4x 50 Kg bags or 200 Kg/ha Ammonium Nitrate which contains 35% N in its grade are used. For organic manure it is recommended to apply 5 tons of composted manure per Lima (1/4 of a hectare) or 20 tons per hectare. However, such a huge application does not show us yet how much nitrogen N we have added to the soil

(Mingochi *et. al*., 2000). Chicken manure has a decomposition or mineralization efficiency coefficient of 67 % which should be factored in when calculating for actual amounts of manure to be applied in the field (Marschner, 1990; Bacon, 1995).

2.6 Crop performance under Organic and Conventional systems.

A review of a 22 year farming trial study concludes that organic farming produces the same yields of corn and soybean as does conventional farming, but uses 30 percent less energy, less water and no pesticides (Pimentel, 2005). The study compared a conventional farm that used recommended fertilizer and pesticide application with an organic animal-based farm (where manure was applied) and an organic legume-based farm (that used a three- year rotation of hairy vetch/corn and rye/soybean and wheat). The two organic systems received no chemical fertilizers or pesticides. The research compared soil fungi activity, crop yields, energy efficiency, costs, organic matter changes over time, nitrogen accumulation and nitrate leaching across organic and conventional agricultural systems. It was found that corn and soybean yields were the same across the three systems. It was also observed that although organic corn yields were about one-third lower during the first four years of study, overtime the organic systems produced higher yields, especially under drought conditions (Pimentel, 2005). The reason was that wind and water erosion degraded the soil on the conventional farm while the soil on the organic farms steadily improved in organic matter, moisture, microbial activity and other soil quality indicators (Pimentel, 2005). Among the study’s other findings, it was observed that in the drought years of 1988 to 1998, corn yields in the legume based system were 22 percent higher than yields in the conventional system. The nitrogen levels in the organic farming systems increased 8 to 15 percent. Nitrate leaching was about the equivalent in the organic and conventional farming systems. Organic farming reduced local and regional groundwater pollution by not applying agricultural chemicals (Pimentel, 2005).

Coupling long-term cropping research with rigorous replication yields reliable results. (Delate, 2007). The research tested whether organic systems relying on inputs such as composted manure can promote stable yields, soil quality and plant protection. The results were compared with a corn-soybean (C-S) rotation supported by greater levels of externally acquired inputs such as fossil energy based fuels. The rotations used on the organic plots have been corn- soybean- oat/ alfalfa (C-S-O/A) and corn- soybean- oat/ alfalfa- alfalfa (C- S- O/ A- A). Organic crop yields were equal to conventional plots in the three years of transition. In the fourth year, organic corn yields in the longest rotation outpaced those of conventional corn. Organic soybean also out-yielded conventional soybean in the fourth year of the rotation. The research also reported remarkable consistency of yields during the first three transitional years. One of the things that set the research apart in addition to its length and design is that the plots were 42 m x 21m, large enough to accommodate conventional farm equipment (Delate, 2007).

The organic plots were amended in early spring with composted swine manure. These plots were then disked, rotary hoed and cultivated with an average of two row cultivations per year. On the organic plots, the organic matter from the composted manure quickly helped enhance the resilience of the soil. Key to this organic matter and supply of nutrients is the fact that biologically active nutrients can be tapped by the plant when temperature and moisture drives availability (Delate, 2007). The ultimate benefit which can be derived from the long-term project is to maximize confidence in the data and to monitor any unexpected results that appear over longer periods of time. Researchers will continue to examine the effects of crop sequence on long term pest disruption and attraction of beneficial insects to the organic system (Delate, 2007).

3.0 MATERIALS AND METHODS

3.1 Site and Design

The study was carried out at the University of Zambia (UNZA), School of Agricultural Sciences Field Station.

The Field Station of the University of Zambia falls under Lusaka district which lies between latitudes 14 to 16^0 S and 28 to 30^0 E. According to agro- ecological conditions (based on temperature and moisture supply), the area lies in Region II of Zambia. This region receives a total annual rainfall of between 800 to 1000mm. Temperatures range from about 28 ^{0}C to 38 ^{0}C during the hot season and 4 ^{0}C to 18 ^{0}C in the cold season. It has a favorable combination of both good climate and soils for most crops including rape. An initial soil characterization was carried out to form a basis of nitrogen fertilizer application rates as shown in Table 1.

Table 1: Average selected soil properties for the two plots used in the study

Site	pH $CaCl_2$	N %	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg
Conve	6.35	0.18	0.21	72.67	1112.50	97.92
Org	6.50	0.05	1.19	75.67	1391.67	153.33
	Fe mg/kg	**Sand %**	**Clay %**	**Silt %**	**Texture class**	**Soil color**
Conve	1.35	46.8	32.0	21.2	Clay loam	Reddish gray
Org	1.60	45.8	27.0	27.2	Clay loam	Reddish gray

3.2 Treatments

The study was conducted during the 2008/09 season under irrigated conditions. The treatments used three rape vegetable varieties; English giant (an exotic variety) Nanga and Prior (local varieties). The two farming methods as represented by the nitrogen sources were prepared as described below.

The inorganic fertilizer used as a source of N for basal dressing under the conventional farming practice was compound- D whose grade is 10: 20: 10 (N:P:K).

For the organic fertilizer, uncomposted chicken manure, and two composted products of chicken manure were used. The compost heaps were made at different times to give different decomposition levels in descending order with one of the heaps being allowed to fully decompose (High) as described by Bacon (1995). One heap was composted for 14 weeks to achieve partial decomposition (Moderate) and the other was undecomposed (Low).

The compost heaps were then characterized for the total and available levels of selected elements as shown in Table 2

Table 2: Nutrient content of Chicken manure compost

	Total N, P and K			Available N, P and K			
Compost	**N %**	**P %**	**K %**	**NH4-N g/Kg**	**NO3-N g/Kg**	**P g/Kg**	**K g/Kg**
Undecomposed	1.56	5.03	2.27	3.63	0.12	0.89	10.54
Partially decomp	2.21	3.03	3.37	3.07	0.39	0.82	9.71
Fully decompd	1.17	2.23	2.45	0.41	0.62	0.56	6.67

3.3 Land Preparation

The plots used for the trial were initially ploughed using a tractor. Later on, hand hoes were used to make raised beds and bring the soil to a fine tilth.

3.4 Planting

The rape seeds for conventional farming together with the thoroughly washed organic seeds were separately sown in seed trays using soil from an old abandoned compost heap made almost three years ago. They were later put in the green house. This was done in order to provide a common starting point before transplanting them onto the main plots. The seedlings were transplanted from the green house to the main plots after three weeks and were not given basal dressing fertilizer for two weeks until they were established in order to confirm as to whether they had a common start even on the main plots. As a basal dressing, the inorganic and the organic fertilizers were measured to supply quantities of nitrogen equivalent to 10, 20 and 50 Kg N/ha. The amounts of inorganic and organic fertilizers applied to supply the desired rates of N per bed are given in Table 3.

Field Layout and Experimental design

The treatments were arranged in a Strip-Split Plot Design. Each main plot measured 10 m x 20 m to which was applied two different sources of nitrogen, namely inorganic and organic respectively (Gomez and Gomez, 1984; Stern *et. al*. 2004). The two main plots were separated by a strip of 30 m in between. The sub-plots comprised of 27 beds each measuring 1 m x 2 m. On these beds were planted three rape varieties which were replicated three times.

Table 3: Calculated nutrient contributions of different treatments of materials used as basal application in the study.
Farming method.

Conventional				Organic		
Nitrogen level	**Nutrient level**	**Kg/ha D-comp Equiv.**	**Kg/ Bed**	**Treatment level**	**Kg/ha Manure Equiv.**	**Kg/Bed**
Low	10	100	0.074	Undecompod	955	0.708
Medium	20	200	0.148	Partially decompd	1350	1
High	50	500	0.37	Fully decompd	6380	5

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3.5 Weed, Pest and Disease Control

Early weeding was carried out on both plots, using hand hoes to remove weeds between and within rows. Though the weed population was negligible, both plots were weeded twice during the course of the trial. The first one was done two weeks after transplanting and the second one three weeks later.

Pests were controlled as and when necessary. The common pests were aphids and grasshoppers. From the nursery in the green house, the variety English Giant was already attacked by aphids while the other two varieties were not. The first pest control on both plots was done a day just after transplanting to keep the aphids and grasshoppers away. For the plot under conventional farming, this was done by spraying Endosulphan at the rate of 30ml to 10 litres of water. To control aphids on the plot under organic farming, *Lantana camara* leaves were crushed and soaked overnight into 20 l of water. A standard empty bag of a 10 Kg tested seed with dimensions of 35 cm x 54 cm was used for packing the leaves. To keep grasshoppers away on the plot under organic farming, the same grasshoppers were captured, crushed and soaked in water overnight and the solution was later sprayed onto the plants. Pest control was done every 2 weeks on the organic farming plot while it was every month on the plot under conventional farming.

3.6 Data collection.

During the growth period of the crop after transplanting, the plant height, leaf number, leaf width and length were recorded. Plant height was measured from the soil surface to the whorl of the flag leaf. Measurements were made on five randomly selected plants per treatment per variety in a replication. The leaf width was measured from the widest part of the leaves per plant from the same five plants randomly selected.

3.7 Harvesting.

Harvesting was done when the leaves reached maturity, 8 weeks from the date of sowing. This was achieved by plucking out all the leaves except the last top three per bed. These were counted before being put in a labeled paper bag for subsequent weighing.

The selected elements in the soil were analyzed to help explain the differences or similarities of the yield response of rape by knowing the initial and final available quantities. A reliable index of the amount of each element supplied to the crop from the soil is a pre-requisite to efficient utilization of the element. The total N in the soil was determined by the Kjeldahl procedure. The P content was determined by using the Bray-1 procedure and readings taken at 650nm on a colorimeter. Exchangeable K, Ca and Mg were determined by extraction with 1M ammonium acetate solution and the concentration of each cation were measured using the Atomic Absorption Spectrophotometer (AAS). Iron was determined using of the DPTA-TEA extracting solution and the concentration in solution was measured on an AAS (Cottenie, 1982).

To help explain the differences or similarities in yield response of rape grown under organic and conventional farming practices, selected elements were measured. A plant that is not suffering from the lack of any particular element should have in its tissues at least a certain minimum or critical percentage of each mineral element that is needed for its growth. If it contains less than this minimum, a deficiency probably exists. Whole leaf samples in each weighed paper bag were separately dried in the oven. To obtain homogeneous samples, the samples were ground using a Wiley mill, fitted with a 1.0 mm sieve. After grinding each sample the mill was cleaned to avoid cross contamination. The ground samples were kept in labeled and tightly wrapped paper bags.

To determine P, K, Ca and Mg, a gram of oven-dry and ground sample of plant tissue was digested in concentrated nitric acid with hypochloric acid until the solution was clear. The AAS was then calibrated with each element's standards. Phosphorus was determined in a single solution of dilute nitric acid read at 882 nm. Iron was determined by first ashing the sample until it turned white and adding nitric acid to the ash which was then filtered. The concentration of Fe in the solution was then read on the AAS. To determine the total N content of the leaves, a gram of oven-dried and ground sample of plant tissue was digested in concentrated sulphuric acid and then the modified Kjedahl method was followed (Cottenie et al., 1982).

3.8 Data Analysis.

Capturing and exploration of all data was carried out in excel spread sheet while statistical analysis was performed using computer software package SAS (6.12). After testing for normality the data was subjected to Analysis of Variance (ANOVA) that was used to test for significant differences among treatments. Differences between treatment means were declared significant at $P<0.05$ and treatment means found to be significantly different were separated by the Duncan Multiple Range Test (DMRT). To determine differences in treatment viability between conventional and organic farming practices, coefficient of variation (CV), which is a measure of scatteredness of data was used (Gomez and Gomez, 1984; Stern *et. al*. 2004).

4.0 RESULTS

4.1 General.

The prevailing climatic conditions for Lusaka under which the UNZA Field station falls, for the period of the experiment are given in Appendix 1. Data on the fertility status of the soil for the two plots before planting is also given in Table 1. The results were analyzed according to the three treatments given to the study as shown in Table 4.

Table 4: Combined Analysis Of Variance (ANOVA) on measured variables of Rape grown during the 2008/09 season at UNZA Field Station

Mean Squares							
Sources of Variation	**Deg. of freedom**	**Number of leaves**	**Leaf width**	**LAI**	**Leaf Yield**	**Tissue N**	**Soil N**
Replication	2	18	5.17	432.39	9814.5	2342.73	279.02
A (Nitro)	2	94.5	20.39	3975.06	5114.06	5667.62	30.30
Error (a)	4	17.67	7.64	3086	1784.14	5270.98	28.74
B (Variety)	2	228.22*	22.17*	61.06	8877.56	435.6	22.24*
Error (b)	4	8.72	0.34	135.11	2098.06	7493.98	2.10
A x B	4	43.14	2.64	684.61*	374.20	4242.54	3.63
Error C	8	11.22	3.06	84	253.03	3640.51	3.28
C(Farming Method)	1	1224.52*	21.4*	6315.85*	4302.3	12.5	427.85
A x C	2	17.57	6.36	1091.35*	313.13	5726.74*	89.19*
B x C	2	32.52*	0.91	6891	2701.4	7121.44	3.58

*Significant at P < 0.05

4.2 Measured Variables

4.2.1 Number of leaves

The Nitrogen levels caused significant differences ($P<0.05$) in number of leaves per plant. The highest mean (20) leaves per plant was observed under nitrogen level of 50 Kg N/ha while those at 10 and 20 Kg N/ha were not significantly different (Tables 4 and 5).

Table 5: Effect of Nitrogen Levels on Measured Variables of Rape grown during the 2008/09 season at UNZA Field Station

Treatment	#of leaves (number)	Width (cm)	LAI	Yield (kg/ha)	Tissue N (%)	Soil N (%)
Low 10	16.611_b	8.722_a	35.833_b	54.83_{ab}	0.24_a	0.26_{ab}
Moderate 20	15.111_b	7.00_b	26.722_b	33.39_b	0.20_b	0.28_a
High 50	19.611_a	8.944_a	55.50_a	69.39_a	0.23_{ab}	0.26_{ab}
Mean	17.11	8.22	39.35	52.54	0.22	0.27
C.V	14.96	17.38	26.66	68.16	14.98	18.40

* **M**eans with the same letter are not significantly ($P < 0.05$) different

Varieties caused significant differences ($P<0.05$) in the number of leaves per plant. The variety Nanga had the highest mean (20) leaves per plant while the variety of English giant had the lowest (13) leaves (Tables 4 and 6).

Table 6: Effect of Variety on the Measured Variables of Rape grown during the 2008/09 season at UNZA Field Station

Treatment	#of leaves (number)	Width (cm)	LAI	Yield (Kg/ha)	Tissue N (%)	Soil N (%)
Eng. Giant	13.444_c	9.444_a	37.389a	74.50_a	0.23_a	0.28_a
Nanga	20.556_a	7.278_b	40.944_a	50.33_{ab}	0.23_a	0.26_b
Prior	17.333_b	7.944_b	39.722_a	32.78_b	0.22_a	0.26_b
Mean	17.11	8.22	39.35	52.54	0.22	0.27
C.V	14.96	17.38	26.66	68.16	14.98	18.40

* **M**eans with the same letter are not significantly (P < 0.05) different

Differences were observed between the conventional and organic farming practices for number of leaves per plant. Conventional farming gave a higher mean (19) leaves per plant compared to a lower mean (16) under organic farming (Tables 4 and 7).

Table 7: Effect of Farming Method on Measured Variables of Rape grown during the 2008/09 season at UNZA Field Station.

Treatment	# 0f leaves (number)	Width (cm)	LAI	Yield (kg/ha)	tissue N (%)	Soil N (%)
Conventional	18.6296_a	8.8519_a	50.074_a	62.26_a	0.22_a	0.24_b
Organic	15.5926_b	7.5926_b	28.630_b	42.81_a	0.22_a	0.30_a
Mean	17.11	8.22	39.35	52.54	0.22	0.27
C.V	14.96	17.38	26.66	68.16	14.98	18.40

* **M**eans with the same letter are not significantly (P<0.05) different

The interactions between varieties and the farming methods were significant for number of leaves. On both methods, the variety English giant appeared to be more susceptible to attacks by both aphids and grasshoppers. No diseases were observed on both methods for all the varieties of rape during the study period. There was a decrease on the number of leaves for English giant and Nanga across the different farming methods. However, Prior did not show any change in magnitude (Tables 4 and 8).

Table 8: Interaction effects of Variety and Farming method (B x C) for number of leaves (number).

Farming Method	Varieties		
	Eng. Giant	**Nanga**	**Prior**
Conventional	16.00	22.56	17.33
Organic	10.89	18.56	17.33
Mean	13.45	20.56	17.33
C.V	19.04	12.45	14.78

4.2.2 Leaf width (cm)

Nitrogen levels caused significant difference on leaf width. The least width mean obtained was 7cm under the level of 20 Kg N/ha while the other two levels were not significantly ($P<0.05$) different (Tables 4 and 5).

Varieties also caused significant differences on leaf width. English Giant had the widest mean (9.444 cm) while the least mean (7.278 cm) for Nanga was not significantly different from that of Prior (Tables 4 and 6).

The farming methods caused significant differences on leaf width. Conventional farming had wider mean (8.85 cm) compared to (7.59 cm) for organic farming (Tables 4 and 7).

4.2.3 Leaf Area Index

The nitrogen levels indicated significant differences for LAI. The highest LAI mean (55.5) was observed under the nitrogen level of 50 Kg N/ha. The other two nitrogen levels were not significantly different (Tables 4 and 5).

There were no significant differences observed between varieties for LAI. .Significant differences for LAI between the farming practices were observed. Conventional farming gave a higher mean (50) compared to (28.6) for organic farming (Tables 4 and 7).

Significant interactions between the nitrogen levels and variety as well as the nitrogen levels and the farming methods for LAI were observed. There was a noticeable drop in magnitude of LAI at 20 Kg N/ha followed by a sharp rise at 50 Kg N/ha across varieties (Tables 4 and 9).

Table 9: Interaction effects of Nitrogen levels and Variety (A x B) for LAI

Treatment	Varieties		
	Eng. Giant	**Nanga**	**Prior**
Low 10	32.33	41.83	33.33
Moderate 20	33.00	29.83	17.33
High 50	46.83	51.17	68.50
Mean	37.39	40.94	39.72
C.V	28.06	25.62	26.41

LAI decreased per nitrogen level across the different farming methods as evidenced by the negative change in magnitudes (Tables 4 and 10).

Table 10: Interaction effects of Nitrogen levels and Farming method (A x C) for LAI

Farming Method	**Treatment**		
	Low 10	**Moderate 20**	**High 50**
Conventional	39.33	36.67	74.22
Organic	32.33	16.78	36.78
Mean	35.83	26.73	55.50
C.V	29.28	39.24	18.90

4.2.5 Plant Tissue N

No significant differences (P<0.05) were observed among the tested treatments (varieties, nitrogen levels and farming systems) for plant tissue nitrogen (Tables 4, 5, 6 and 7).

Significant interactions, however, were observed between the nitrogen levels and the farming methods for plant tissue N. There was an increase in mean plant tissue N at 20 Kg N/ha and 50 Kg N/ha across the two farming methods (Tables 4 and 11).

Table 11: Interaction effects of Nitrogen levels and Farming method (A x C) for Tissue N (%)

Farming Method	Treatment		
	Low 10	**Moderate 20**	**High 50**
Conventional	2.57	1.99	2.15
Organic	2.18	2.08	2.46
Mean	2.38	2.04	2.31
C.V	13.84	16.15	14.26

4.2.6 Residual Soil N

The nitrogen levels were not significantly different (P<0.05) for residual soil N. However, varieties were significantly different for residual soil N. English giant had the highest mean (0.28%) while the other two were not different (Tables 4 and 6).

Significant differences were observed between the farming methods for soil N. Residual soil N was higher (0.30%) under organic farming system compared (0.24%) under conventional farming (Tables 4 and 7).

Significant interactions between the nitrogen levels and the farming methods were observed (P<0.05) for soil N. An increase of soil N was observed per nitrogen level across the two farming systems as evidenced by the positive change in magnitudes (Tables 4 and 12).

Table 12: Interaction effects of Nitrogen levels and Farming method (A x C) for Residual Soil N (%)

Farming Method	Treatment		
	Low 10	Moderate 20	High 50
Conventional	0.21	0.27	0.23
Organic	0.32	0.29	0.28
Mean	0.27	0.28	0.26
C.V	18.36	17.70	19.06

4.2.4 Leaf yield

No significant differences (P<0.05) were caused by nitrogen levels on leaf yield, although relative high leaf yield mean of 69.39 kg/ha was observed under 50 Kg N/ha compared to 33.39 kg/ha under 10 Kg N/ha (Tables 4 and 5).

There were no significant differences (P<0.05) caused by variety on leaf yield.

Though a higher mean of 62.26 kg/ha for leaf yield was recorded under conventional farming, it was not significantly different ($P<0.05$) from a lower mean of 42.81 kg/ha observed under organic farming (Tables 4 and 7).

5.0 DISCUSSION

Most studies have attributed the yield response of plants to some physical inputs such as light, temperature, nutrients and water supply (Thurling, 1974). Yield levels obtained under farmer conditions are usually low. Some of the major causes for these low yields are the low use of external sources of nutrients and the near absence of fallows long enough to restore the soil nutrient base (Vanlauwe *et. al*., 1999).

Soil nutrient depletion which is usually indicated by negative nutrient balances is the most important single cause of these low yields (Hoyt *et. al*., 2006). Reversal of soil fertility depletion is required to increase per capita agricultural production. Use of inorganic fertilizers is one of the ways of addressing this situation but is constrained by the high costs that the resource poor farmers cannot afford (Vanlauwe *et. al*., 2002). A study by Odhiambo (1994) revealed that the rising cost of inputs has resulted in many smallholder farmers reducing or abandoning the use of inorganic fertilizer altogether.

To mitigate the aforementioned problem, our study endeavored to evaluate the performance of Rape (*Brassica napus)* grown under organic farming compared to conventional practices. The overall objective of the study, therefore, was to provide evidence of the potential of organic farming. The results of the study show that conventional farming had a higher leaf yield (1.6 tons/ha) compared to organic farming (1.2 tons/ha). The consistently higher yields recorded under conventional farming was attributed to higher amounts of nutrient nitrogen (three times higher) which was found in the soil at the start of the experiment. The leaf yields of 1.6 tons/ha for conventional farming and 1.2 tons/ha for organic farming was generally very low and reflected the prevailing conditions under which the study was carried out. However, the yield result obtained agrees with a report made by Mingochi (2000) that though rape has a very high yield potential of 22 tons/ha, the actual average yield can fall below 10 tons/ha. He further suggested that the wide gap between the potential and actual yield could be due to many factors which may include low or no fertilizer application, improper selection of suitable cultivars and inappropriate cultural practices under farmer's condition. In this study the extraneous factors contributed to the low yields.

It has been established that although nitrogen nutrition increases LAI, anything that attacks and destroys the leaf will eventually reduce LAI and subsequently reduce the yield (Butler and O'Neil, 2007). During the study, it was observed that crops under organic farming were under constant attack from the leaf eating pests. This could be one reason why yield from organic farming was lower. This is in agreement with a report made by Butler and O'Neil (2007) that disease and pest management has important effects on LAI and ultimately yield. It is important to note that the leaf yield obtained from organic farming was 70% of those obtained from conventional farming. This is well above and in agreement with an observation made by Pimentel (2005) that organic corn yields were about one- third lower than the conventional corn yields during the first four years of study and overtime the organic systems produced higher yields especially under drought conditions. It is important to note that though the leaf yields from organic farming were lower than those from conventional farming, the two yields were not statistically different ($P<0.05$). Studies have shown that manure is the most widely used organic fertilizer by approximately 80% of households (Kihanda, 1996). However, in the majority of farms, the available manure is not enough to fertilize the farms and the limited access to sufficient inorganic fertilizer continue to result in declining crop yields. There is therefore, an urgent need to develop and promote alternative appropriate technologies that will replenish soil nutrients to enable farms to be more productive. The results of this study have shown that composted organic source of nutrients has potential and could therefore be considered as a better viable option in increasing and providing a more balanced supply of nutrients in vegetable production.

In order to meet the ever rising food demand, there is need to explore and promote alternative technologies that will replenish soil nutrients to enable farms to be more productive. One of the approaches is the nutrient management that makes use of organic inputs. The beneficial effects of organic sources on soil fertility, crop yields, and maintenance of soil organic matter have repeatedly been shown in field trials (Nandwa, 2003; Vanlauwe *et. al*., 2002), yet there are no predictive guidelines for their management, such as those that exist for inorganic fertilizer. The success of nutrient management depends on several factors that include types and quantities of organic materials available, and the levels and mineralization at which the nutrient sources are used (Vanlauwe *et. al*., 2002). Research on these issues is scanty and as such guidelines for their use and management are lacking.

The specific objective of the study was to evaluate manure as a source of nutrient nitrogen for plant growth. The results of the study show that the nitrogen level at 50 Kg N/ha gave the highest mean yield (69.39 kg/ha). This was followed by the mean yield (54.83 kg/ha) at nitrogen level 10 Kg N/ha. The lowest yield mean (33.39 kg/ha) was recorded at nitrogen level 20 Kg N/ha. This agrees well with reports made by other researchers that the success of nutrient management depend on the levels at which the nutrient sources are used (Vanlauwe *et. al*., 2002; Nandwa, 2003). Milthorpe and Moorby (1979) also reported that nitrogen level affects the rate of leaf expansion and its final size, which ultimately contributes to the yield.

The nitrogen level at 10 Kg N/ha recorded a yield mean (54.83 kg/ha) which is higher than the yield mean (33.39 kg/ha) at 20 Kg N /ha. This is in agreement with the report made by Chang –Seng (1990) who suggested that higher yields can still be recorded even under low nitrogen levels because of the ability of the plant to optimize the use of absorbed nutrients in meeting its metabolic functions such as dry matter accumulation. The ability of the plant to use nutrients is enhanced by its photosynthetic efficiency under sub- optimal conditions (Chang-Seng, 1990). The lower yield in manure treatment (20 Kg N/ha) could be attributed to lower rates of manure decomposition and therefore slow rate of availing nutrients to the crop. However, it is important to note that though the highest nitrogen level (50 Kg N/ha) gave the highest yield mean (69.39 kg/ha) as compared to the other two, the yield means were not significantly different ($P<0.05$).

The yield mean (62.26 kg/ha) for conventional farming was higher than the yield mean (42.81 kg/ha) for organic farming. There was a yield gap between conventional and organic farming. This was mainly attributed to differences in management practices arising from lack or partial adoption of recommended rates (Vanlauwe, *et. al*., 2002). The results were in agreement with a report made by Lee and Kader (2000) that among environmental factors that impact vegetable yield include production practice (organic versus conventional). However, the higher yield mean for conventional farming and the lower yield mean for organic farming were not statistically different ($P<0.05$). There is need to do more research to adjust the organic nitrogen levels in order to come up with specific and independent recommended application rates. The results of this study show that both the nitrogen levels and nutrient sources were not statistically different for yield, implying that the organic source of nutrients is as good as the conventional source. This underscores the importance of organic source of nutrients being a viable alternative option for vegetable production.

6.0 CONCLUSION.

The nitrogen application levels, varieties and the farming methods used in the study were not statistically different for yield. This is in agreement with previous experiments done by other scientists comparing yield responses of crops grown under both conventional and organic farming practices. Even though the yields of 1.6 tons/ha from the conventional plot were higher compared to 1.2 tons/ha for the organic plot, the difference was not statistically significant. The results show that organic farming yields compares well with conventional yields under the prevailing conditions of the study. The overall conclusion is that nutrient nitrogen applied as organic manure supports plant growth and development and presents itself as a viable alternative option for vegetable production

Such experiments should have concurrently running trials both under a controlled environment and in the field. Emphasis must be laid on disease and pest management of organic crops with long term projection to enable achievement of repeatable results. Getting same results overtime becomes much more credible to farmers, scientists and policy makers.

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APPENDICES

Appendix 1: Minimum, Maximum and Mean Monthly Air Temperatures for Lusaka for 2008.

Month	Minimum Temp.(c)	Maximum Temp. (c)	Mean Temp. (c)
Jan	17.0	26.5	21.8
Feb	16.9	26.3	21.6
Mar	16.6	26.6	21.6
Apr	14.9	26.3	20.6
May	12.7	24.8	18.7
Jun	10.2	22.9	16.6
Jul	10.0	22.8	16.4
Aug	12.2	25.6	18.9
Sept	15.3	29.1	22.2
Oct	17.4	30.4	23.9
Nov	17.8	29.7	23.8
Dec	17.2	26.8	22.0

Source: Department of Meteorological Services, Lusaka, Zambia

Appendix 2: Average content (%) of selected plant tissue elements

	Nitrogen N	Phosphorus P	Potassium K	Calcium Ca	Magnesium Mg	Iron Fe
Organic	0.22	0.62	11.04	4.88	1.41	0.18
Conventional	0.22	0.58	14.09	3.73	1.17	0.14