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USE OF VERMICOMPOST AS A SOIL SUPPLEMENT ON GROWTH AND YIELD OF RAPE (*Brassica napus*)

Mugwendere Terence, Mtaita Tuarira*, Mutetwa Moses* and Tabarira Jefta

Department of Horticulture, Faculty of Agriculture and Natural Resources, Africa University, Box 1320, Old Mutare, Zimbabwe

***Corresponding authors' e-mail: tamtaita@africau.edu;mosleymute@gmail.com**

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Rape (*Brassica napus)* is an important and widely grown vegetable crop for food and income generation in most homesteads around Zimbabwe. Most households in Zimbabwe use inorganic fertilizers to improve production of rape in sandy soils which in turn are robbing the soil of its fertility. The present study investigates the effects of vermicompost as a soil supplement on growth and yield of rape compared to chemical fertilizers. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. A set of different vermicompost treatments (2.1%, 4.2%, 8.0%, 12.5%, and 12.5%) and inorganic fertilizer treatments (0.25%, 0.33% and 0.4%) were compared. Results revealed that the inorganic fertilizer treatments favored the growth and yield of rape more than vermicompost treatments. The inorganic fertilizers had quicker rate of release of nutrients as well as higher level of plant available nutrients. Likewise, the number of leaves, leaf length, number of marketable leaves, fresh yield mass, leaf width and whole length was also significantly better in case of inorganic fertilizer treatments. Generally, all treatments varied ($p<0.05$) as the growth progressed. There was significant interaction ($p<0.05$) between the treatments at 10 day intervals which was expressed in cumulative number of leaves and number of marketable leaves. It was concluded that use of vermicompost alone as a soil supplement in sandy soil for production of rape lead to lower growth and consequently yield responses. Hence the sole use of vermicompost as soil supplement should be discouraged and an integrated nutrient management plan may be evaluated as the most logical solution.

Keywords: Rape (*Brassica napus),* vermicompost, inorganic fertilizers, nutrients, growth, yield

INTRODUCTION

Environmental degradation is a major issue of concern across the globe in the 21st century. The international community, at the Rio +20 Earth Summit, agreed to 'Zero Net Land Degradation' as a sustainable development goal highlighting the unrestrained and constant uses of agro-chemicals by farmers as one of the major causes of land degradation (The United Nations Convention to Combat Desertification, 2012). The deterioration of soil fertility through loss of nutrients and organic matter, erosion, salinity and pollution of the environment can be linked to the use of agro-chemicals in conventional agricultural practices (Garg *et al.*, 2008).

There is a growing concern to decrease the application of chemical fertilisers to soil because of their adverse effects on soil fertility, human health and the environment (Nagavallemma *et al.*, 2004). Inorganic fertilisers are proven to be destructive in every way that is, environmentally, socially, agronomically and economically (Sinha *et al.*, 2011). Rampant application of chemical fertilisers to crops has negative effects on the soil flora, fauna and enzymes which help to maintain the natural fertility of the soil (Gupta *et al.*, 2014). Horticulturists are advocating the adoption of vermicomposts as a switch from the destructive chemical fertilisers (Sinha *et al.*, 2011). Vermicomposts are nutrient-rich, microbiologically-active organic materials that result from the interactions between earthworms and mesophilic microorganisms, in a non-thermophilic process, during the breakdown of organic matter to produce fully-stabilized materials (Lazcano and Dominguez, 2011; Thiruneelakandan and Subbulakshmi, 2014; Joshi *et al.*, 2014). According to Dominguez (2011) vermicomposts are produced using a mesophilic bio-oxidative process in which earthworms, primarily epigeic or litter-feeding species such as *Eisenia foetida* and *Lumbricus rubellus* and associated microorganisms and other soil decomposers interact to break down organic wastes. They are highly fragmented, soil-like, organic materials with exceptional biological, chemical and physical properties (Brown, 2000; Edwards, 1998; Orozco, 1996).

This vermicomposting is an organic farming technique that is gaining recognition amongst small scale farmers across the globe as a natural means of soil fertility management, fitting well into the integrated plant nutrient management strategies for sustainable agriculture (Sharma, 2001). Organic fertilisers from animal manure, yard waste, human waste and food waste that have been bio-stabilised using vermicomposting are now becoming a preferred source of local fertiliser input by small scale farmers in many parts of the world for soil amendments and improved crop production.

The use of vermicomposts is not an unusual practice in most countries in Sub-Saharan Africa, although its adoption by farmers in the region is still very low. Many small scale farmers in the region cannot afford chemical fertiliser inputs and depend on organic fertilisers like compost and manure, but are oblivious of vermicomposts (Svotwa, 2009). Evidence has been provided that the application of vermicompost on cowpea (*Vigna unguiculata*) field plots enhances the crop's aerial biomass production. A few small scale farmers in Southern Africa, mainly South Africa, Malawi and Zimbabwe have also adopted the use of vermicomposts.

Some small scale farmers in Matebeleland who have been using chicken manure vermicompost for several years in their gardens have reported enhanced soil productivity and plant growth and crop yields over the years. In other parts of Zimbabwe, demonstration by the Agricultural Technical and Extension Services on vermicomposting has promoted the adoption of these vermicomposts. Small scale farmers in Hwedza, Zimbabwe are reaping the fruits of using vermicomposts as they are able to harvest and sell tomatoes on a daily basis from green houses and open fields (Mangwarara, 2014).Vegetables and cereal crops grown in soils amended with vermicompost display excellent growth performances in terms of plant height, colour and texture of leaves and appearance of fruiting structures when compared to conventional compost and chemical fertilisers (Sinha, 2009).

The use of permaculture practices such as hugelkultur, rainwater harvesting, sheet mulching, intensive rotational grazing and in particular vermicomposting and its end products has the potential to allow small scale farmers to realise increase in crop production and prevent harmful pests without polluting the environment. Therefore, integration of vermicomposts into nutrient management plans by small scale farmers could result in significant reduction in their cost of production. The present study was undertaken to investigate the effects of vermicompost produced from cattle manure, food waste and garden waste as a soil supplement on growth and yields of rape (*Brassica napus*) in potting media.

MATERIALS AND METHODS

Crop establishment and Experimental design: The experiment was conducted at Africa University Farm located at 18°53'70.3" South and 32°36'27.9" East and at an altitude of 1131m. The investigation included 9 treatments with 3 replications in 3 gallon plastic pots. Six kilograms near neutral soil was used per pot. The soil media in each pot was substituted with the corresponding treatment. The trial was laid out in a Randomized Complete Block Design (RCBD).

Five different levels of vermicompost soil supplemtnt were made at the rates of 2.1%, 4.2%, 8%, 12.5% and 17%. The different application rates for each of the five treatments were made by mixing the different levels of vermicompost with the required amount of potting media for all 27 plots. The characteristics of the soil and vermicompost media are shown below.

			Melich 3 extraction	
Media	pH	Min. Initial N (ppm)	P_2O_5 (ppm)	Exchangeable Cations (meq. %)
				K
Soil	6.7	1.65	14.6	0.24
Vermicompost	7.4	15.7	240.6	0.22

Three different levels of Compound D (7:14:7) fertilizer as lower (15g), recommended (20g) and higher (25g) doses were applied as basal dressing per pot at planting. The treatments with 20g of compound D fertilizer and 4g of ammonium nitrate represented the recommended application rates. Treatments as percentage of the total potting media are as shown below.

1) Control (potting media with no amendments,)- **Trt 1**
2) 2.1% vermicompost (125g)- **Trt 3**
3) 4.2% vermicompost (250g)- **Trt 9**
4) 8.0% vermicompost (500g)- **Trt 4**
5) 12.5% vermicompost (750g)- **Trt 6**
6) 17.0% vermicompost (1kg)- **Trt 2**
7) 0.25% inorganic fertilizer (20g)- **Trt 7**
8) 0.33% inorganic fertilizer (25g)**- Trt 8**
9) 0.4% inorganic fertilizer (15g)- **Trt 5**

Other crop husbandry practices included weed pulling, insect and disease control through application of Thionex EC as a drench, Carbaryl, and Dithane M45 and Copper Oxychloride, respectively. Supplementary irrigation was applied as and when necessary. Seedlings were transplanted into pots at 5 weeks post emergence age. After transplanting pots were watered to field capacity.

Data collection: Variables recording included number of leaves per plant, number of marketable leaves per plant, fresh mass yield per net plot, the length of the longest leaf per plant, the width of the longest leaf per plant and whole length of each plant per plot. Data collection started 4 weeks after transplanting. Three harvests were done at an interval of 10 days. Prior to each harvest, the number of leaves per plant and number of marketable leaves per plant were counted and recorded. The leaf initials and the two youngest leaves were excluded from the total number of leaves and total number of salable leaves. Other variables recorded using a tape measure prior to each harvest included the length of the longest leaf per plant, the width of the longest leaf per plant and whole length of each plant per plot. Leaf area was calculated by multiplying the Leaf Length by the Leaf Width and the product multiplied by the correction factor.

Data Analysis: The analysis of variance (ANOVA) was done according to Gomez (1976) and means separated using the least significant difference (LSD) at P=0.05.

RESULTS

Cumulative number of leaves: Data regarding cumulative number of leaves showed significant differences (P<0.05) for media (Figure 1). The highest cumulative number of leaves of 14.06 was from the 0.33% inorganic treatment while the lowest cumulative number of leaves was from the control at 7.89. The cumulative number of leaves, with regard to weeks also showed significant (P<0.05) differences. There was increase in the cumulative number of leaves as weeks progressed but no significant difference (P>0.05) with regard to media by week (MxW) interactions was observed in terms of cumulative number of leaves.

Number of marketable leaves: There were significant differences (P<0.05) shown in number of marketable leaves with respect to media (Figure 2). The 0.4% inorganic treatment had the highest number of marketable leaves of 22.94 while no marketable leaves were recorded from the control treatment.

There were significant differences (P<0.05) in number of marketable leaves as the weeks were progressing. Week three had the highest number (1.04) of marketable leaves. There was a significant (P<0.05) interaction between media and weeks indicating that media affected number of marketable leaves differently depending on weeks. The grand mean was 0.91.

Fresh yield mass: After all three harvests, there were significant differences (P<0.05) in fresh yield mass among treatment means with regard to media (Figure 3).

The 0.4% inorganic fertilizer treatment outperformed all the other treatments with a fresh yield mass of 250.6 g but was not significantly different from treatment 8 which had a mass of 201.1 g. The lowest mass was recorded from the control treatment (Trt 1) with 36.7 g. There were no significant differences (P>0.05) in all treatments regarding weeks and M x W interactions concerning fresh yield mass. The grand mean was 108.8 g.

Leaf length: There were significant differences (P<0.05) in data pertaining to length of leaves in relation to media (Figure 4). The longest leaves were seen in the 0.4% inorganic fertilizer treatment measuring 37.01 cm and the shortest leaves in the control measuring 13.5 cm.

The length of leaves also showed significant (P<0.05) differences as weeks advanced. Week 1 produced the smallest leaf length of 20.69 cm. There were no significant (P>0.05) interactions between media and weeks for length of leaves indicating that media did not affect leaf length differently depending on weeks. The grand mean was 22.92 cm.

Width of leaves: The comparison of the media treatment means indicate significant differences (P<0.05) in width of leaves (Figure 5). The smallest width was recorded in control measuring 5.87 cm and the longest width in the 0.4% inorganic treatments measuring 16.13 cm.

As weeks advanced, statistical differences (P<0.05) were also noted with regard to width of leaves. Week 3 had the longest width measuring 12.06 cm. There was no significant (P<0.05) MxW interaction with regard to width of leaves. The grand mean was 10.17cm.

Whole length of plants: Data regarding whole length of plants showed significant differences (P<0.05) for media (Figure 6). The treatment with the longest whole length of

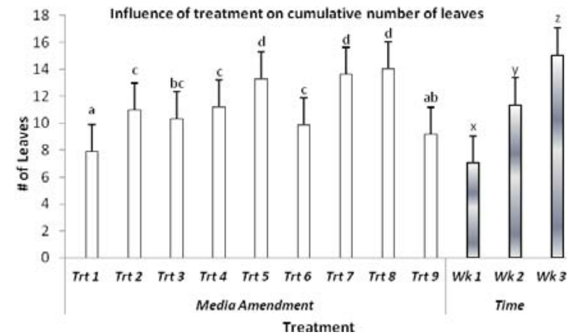

Figure 1: Cumulative number of leaves per treatment.

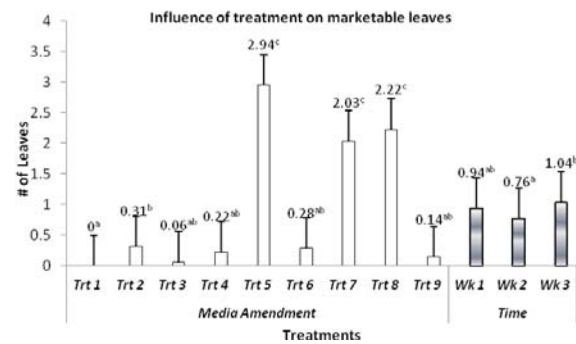

Figure 2: Means of number of marketable leaves per treatment.

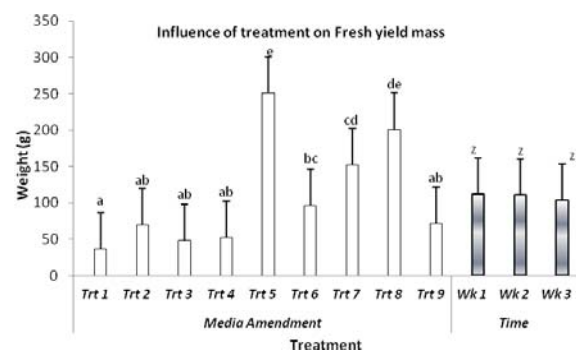

Figure 3: Means of fresh yield mass per treatment.

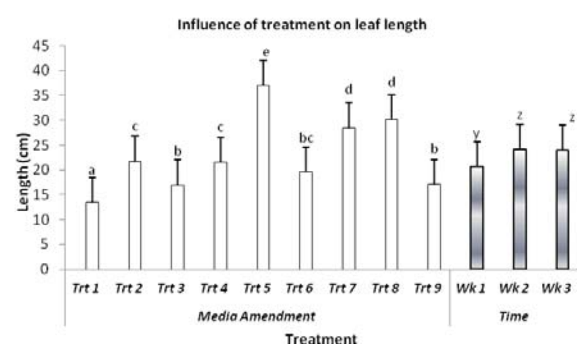

Figure 4: Means of length of leaves per treatment.

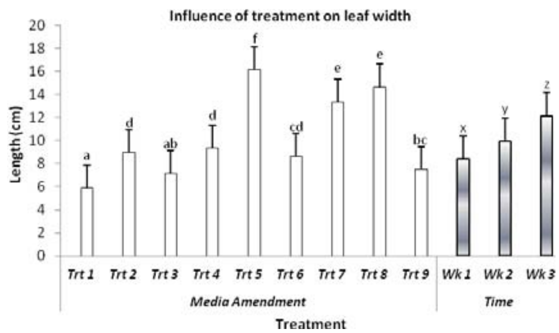

Figure 5: Means of width of leaves.

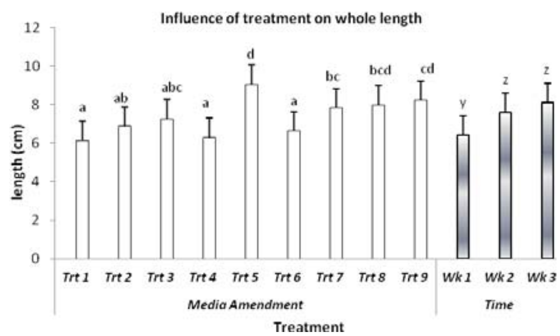

Figure 6: Means of whole length of plants per treatment.

plants of 9.06 cm was from the 0.4% inorganic treatment while the shortest whole length of plants was from the control at 6.14 cm.

The whole length of plants, with regard to weeks, also showed significant ($P<0.05$) differences. There was increase in the whole length of plants as weeks advanced. The plant whole length measurement for week 1, week 2 and week 3 were 6.42, 7.59 and 8.11cm, respectively. There were no significant differences ($P>0.05$) with regard to media by week interactions observed in terms of whole plant length. The grand mean was 7.37 cm.

DISCUSSION

The cumulative number of leaves per plant in the vermicompost treatments and control treatment were lower than the inorganic treatment. Nyakudya *et al*. (2010) also reported similar variation for cumulative leaf numbers per plant with the recommended treatment of poultry manure and inorganic fertilizer treatments as giving higher yields when compared to the biomass treatments. This can be attributed to high nutrient supply in the inorganic fertilizers which increases the photosynthetic activity in rape due to enhanced electron transport rate and biliprotein content and hence increases plant growth and consequently yields (Figueroa *et al.*, 2010). Low cumulative number of leaves in the vermicompost and control treatments was also suppressed by low nutrient value of nitrogen. The cumulative leaf count per plant for all treatments in the experiment followed a descending trend as weeks progressed and was lowest in the control treatment. Nyakudya *et al*. (2010) ascribed this to declining nutrient supply and changes in the developmental stages of rape. The low cumulative number of leaves per plant in the inorganic fertilizer treatments, vermicompost treatments and control treatments could be attributed to ageing of the plant as rape is a fast growing crop whose nitrogen concentration in the tissue decreases due to increase in structural carbohydrates, and hence there was decrease in plant growth variables as the weeks progressed (Zimbabwe Fertiliser Company, 2011). This affected the vermicompost treatments more as there is no synchronization between the slow release mechanisms of vermicompost with the uptake of nutrients by rape.

Data in the experimental study indicated that the 0.4% inorganic fertilizer treatment gave higher value of fresh yield mass when compared to all the other treatments for all three harvests. The results are akin to those by Musara and Chitamba (2015) who attributed this to low values of plant available nutrients required by rape for improved yield in the organic treatment compared to inorganic fertilizer treatments. The low fresh yield mass in the vermicompost treatments can be ascribed to low nitrogen supply which affected the net photosynthetic rate of all crop plants thereby increasing plant growth rate and yield. Wastes used to make the vermicompost, their processing time and maturity are also responsible for the low levels of nitrogen. This could have adversely influenced the photosynthesis process of rape, leading to reduced fresh yield mass (Campitelli and Ceppi, 2008). The inorganic fertilizer treatments' vegetative growth parameters and yields were high from 28 days after transplanting up to the last harvest when compared to the vermicompost treatments and control treatment.

Nitrogen fertilization with ammonium nitrate in the inorganic fertilizer treatments after four weeks from transplanting date increased the leaf length and width of rape during the vegetative growth stage which in turn increases absorption of light energy leading to more yield (Ravi *et al.*, 2008). Fox (1995) attributed the trend to high rates of nitrogen, which increase leaf area development as well as overall crop assimilation. Kumari (2011) also ascribed such increases in leaf area to enhanced nitrogen levels which in turn influence photosynthesis hence increases leaf area. Low levels of humic substances in the vermicompost treatments and control treatments can also be held accountable for reduced leaf length and width in these treatments. Atiyeh *et al*. (2002) worked on crops such as pepper, tomato, strawberry and cucumber. They credited high levels of humic substances in vermicomposts to enhancement of leaf area parameters in these crops. This shows that there were low levels of humic substances in the vermicompost treatments and control treatments and hence the rape leaf length and width variables were adversely affected. The leaf length and width of rape underpin the number of marketable leaves per plant. The inorganic treatments in the investigation had larger number of marketable leaves when compared to all other treatments.

Low numbers of marketable yields in the vermicompost treatments and control treatments can be attributed to high vermicompost and sand soil pH levels which caused the stunting and yellowing of leaf margins in rape resulting in decreased growth and yield as the pH levels fell. Low measurements in leaf length and width for the rape equates to lower number of marketable leaves. But if leaf length and width measurements are high, the number of marketable leaves will also be high. Leaf length and width can therefore be used to determine the number of marketable leaves of rape in the organic and inorganic fertilizer treatments as well as the control. Macro and micronutrients and humic acids facilitate the growth and development of plants (Atiyeh *et al*., 2002; Arancon *et al*., 2005; Fern-andez-Luqueno *et al*., 2010). The whole length of rape per plant was largest in the inorganic fertilizer treatments when compared to all the other treatments. The reduced plant height of rape in this investigation can be attributed to low levels of macro nutrients, micro nutrients and humic acids in the vermicompost treatments and control treatment. Lazcano *et al*. (2010) attributed the increased plant height or whole plant length of tomato to sufficient amount of macro nutrients and micro nutrients in the inorganic fertilizers which increased the growth rate of crop plants when compared to organic fertilizer. Troeh and Thompson (1993) ascribed better whole plant length in inorganic fertilizers treatments when compared to vermicompost treatments to lower levels of phosphorus in vermicompost treatments. Phosphorus is needed by crop plants for energy storage and transfer as its deficiency restricts root growth and proliferation of root hairs in crop plants, hence affecting top growth as less nutrients and humic acids can be extracted by the plant due to the poor root system resulting in stunted growth. Roberts *et al*. (2007) attributed better whole plant length of tomato plants in synthetic fertilizers to lower pH levels compared to vermicompost treatments.

From this investigation, applied vermicompost treatments affected the plant growth characteristics relative to the control treatment. This is confirmed by the significant statistical differences scored for number of leaves, length and width of the leaves, whole length and fresh yield. The results imply a positive influence of the vermicompost to growth and development. Amendments of the growth media with vermicompost had an influence on the nutritional aspect of the media. More nutrients could have been added to the media so that the plants had more uptake of nitrogen leading to improved growth characteristics. Pour *et al*. (2013) and Anwar *et al*. (2005) attributed the physiological changes observed in vermicompost treated plants to the humic substances and increased availability of macro and micronutrients. Atiyeh *et al*. (2002) and Sahni *et al*. (2008) also confirmed that vermicompost contains considerable amount of humic substances and had improving effects on the plant nutrition. Srivastava *et al*. (2012) suggested that the physical and biological properties may be modified in the vermicompost amended soils. Alvarez and Grigera (2005) eluded that vermicompost represented hormone-like activity and increased root growth, thereby enhancing nutrient uptake as well as plant growth and development. Ladan Moghadam *et al*. (2012) also observed similar results with application of vermicompost having favorable effects on the growth, development and physiology on *Lilium asiatic* hybrid var. Navona. Vermicompost contains most nutrients in plant available forms such as nitrate, phosphate, exchangeable calcium, and soluble potassium. Vermocompost has large surface area that provides many microsites for microbial activity and for the strong retention of nutrients for plant growth. Possibly, the plant growth regulators and other plant growth materials like auxins, cytokinins and humic substances in the vermicompost produced by micro organisms had a positive influence on fresh weigh of the seedlings as reported by Sharma *et al*. (2005) and Aalok *et al*. (2008). This could explain the observation of vermicompost amended treatment having an improved performance than the control treatments.

CONCLUSION

Vermicompost supplements have shown to enhance plant growth in several occasions and these growth enhancements could have been attributed to an improvement of the physical, chemical and biological properties of the growing substrate. Generally, replacement of soil with moderate amount of vermicompost produces beneficial effects on plant growth probably due to the vermicompost containing most nutrients in plant available forms such as nitrate, phosphate, exchangeable calcium, and soluble potassium. Vermicompost supplement must have made available a large surface area providing many microsites for microbial activity and for the strong retention of nutrients for plant growth. Such changes in the physical properties of the substrates and presences of humic substances might be responsible for the better plant growth with the doses of vermicompost as compared to the soil-based substrate. However, the use of vermicompost supplements alone in a small scale nutrient management plan led to low growth and consequently low yield responses of rape when compared to inorganic fertilizer treatments. This is mainly due to the low level of nutrient supply and slow mineralization rate of the vermicompost. There is therefore an option of using an integrated nutrient approach that includes vermicomposts and inorganic fertilizers. This will help reduce the adverse effects of using chemical fertilizers alone thereby assisting to maintain soil productivity for longer periods of time.

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REFERENCES

Aalok, A., A.K. Tripathi and P. Soni. 2008. Vermicomposting: A Better Option for Organic Solid Waste Management. J. Hum. Ecol. 24: 59-64.

Alvarez, R. and S. Grigera. 2005. Analysis of soil fertility and management effects on yields of wheat and corn in the rolling Pampa of Argentina. J. Agron. Crop Sci. 191: 321-329.

Anwar, M., D.D. Patra, S. Chand, K. Alpesh, A.A. Naqvi and S.P.S. Khanuja. 2005. Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and basil. Commun. Soil Sci. Plan. 36: 1737-1746.

Arancon, N.Q., C.A. Edwards, P. Bierman, J.D Metzger and C. Lucht. 2005. Effects of Vermicomposts Produced from Cattle Manure, Food Waste and Paper Waste on the Growth and Yield of Peppers in the Field. Pedobiologia. 49: 297–306.

Atiyeh, R.M., C.A. Edwards, J.D. Metzer, S. Lee and N.Q. Arancon. 2002. The Influence of Humic Acids derived from Earthworm Processed Organic Wastes on Plant Growth. Bioresource Technol. 84: 7–14.

Brown, G.G. 2000. Regulation of soil organic matter dynamics and microbial activity in the drilosphere and the role of interactions with other edaphic functional domains. European J. Soil Bio. 36: 177 -198.

Campitelli, P. and S. Ceppi. 2008. Chemical, Physical and Biological Compost and Vermicompost Characterization: A Chemometric Study. Chemometrics and Intelligent Lab. Sys. 90: 64-71.

Dominguez, J. 2011. The microbiology of vermicomposting, pp. 53 - 66. In: Clive A. *et al*., Vermiculture Technology. Taylor and Francis Group, Boca Raton, FL.

Edwards, C.A. 1998. The use of earthworms in the breakdown and management of organic wastes. In: Edwards, C.A., Earthworm ecology: CRC Press, Inc., Boca Raton, Florida, USA London, England, UK.

Fernández-Luqueño, F., V. Reyes-Varela, C.Martínez-Suárez, G. Salomón-Hernández, J. Yáñez-Meneses, J.M. Ceballos-Ramírez and L. Dendooven. 2010. Effect of different Nitrogen Sources on Plant Characteristics and yield of Common Bean (*Phaseolus vulgaris*). Bio-Resource Technol. 101(1): 396–403.

Figueroa, F.L., A. Israel, A. Neori, B. Martínez, E.J. Malta, A. Put, S. Inken, R. Marquardt, R. Abdala and N. Korbee. 2010. Effect of Nutrient Supply on Photosynthesis and Pigmentation to Short-term Stress (UV radiation) in Gracilaria conferta (Rhodophyta). Marine Pollution Bulletin. 60: 1768-78

Fox, R. 1995. The Sewage Solution: Practical Hydroponics and Greenhouse Magazine. Casper publications. http:\\www.hrdoponics.com.au/backissues/issue20.html . Accessed 05 December 2014

Garg, V.K., R. Gupta and A. Yadav. 2008. Potential of Vermicomposting Technology for Solid Waste Management. Current Developments in Solid-state Fermentation. (4): 468-511.

Gupta, R., A. Yadav and V.K. Garg. 2014. Influence of Vermicompost Application in Potting Media on Growth and Flowering of Marigold Crop. Int. J. Recycl. Organic Waste Agric. 3:1-7.

Ladan Moghadam, A.R., Z. Oraghi Ardebili and F. Saidi. 2012. Vermicompost induced changes in growth and development of Lilium Asiatic hybrid var. Navona Afr. J. Agric. Res. 7: 2609-2621.

Lazcano, C. and J. Domínguez. 2010. Effects of Vermicompost as a Potting Amendment of two Comercially Grown Ornamental Plant Species. Spanish J. Agric. Res. 8: 1260-1270.

Lazcano, C. and J. Dominguez. 2011. The use of vermicompost in sustainable agriculture: Impact on plant growth and soil fertility. In: Miransari, M. Soil Fertility. 1st ed. India: Nova Science Publishers, Inc, 2-23.

Mangwarara, A. 2014. Garden Affair: Make money from growing organic crops. The Sunday Mail, 2nd Nov, p.6.

Musara, C. and J. Chitamba. 2015. Growth Rate and Yield of *Brassica napus* in Response to *Acaciella angustissima* Leaf Biomass Application. J. Ani. Pl. Sci. 25: 510-518.

Nagavallemma, K.P., S.P. Wani, S. Lacroix, V.V. Padmaja, C. Vineela, M. Babu Rao and K.L. Sahrawat. 2004. Vermicomposting: Recycling Wastes into Valuable Organic Fertilizer. Global Theme on Agro-ecosystems; Patancheru, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics, 20(8).

Nardi, S., G. Concheri and G. Dell'Agnola. 1996. Biological Activity of Humic Substances. In: Piccolo, A.; Humic Substances in Terrestrial Ecosystems. Elsevier, Amsterdam. 361–406.

Nyakudya, I.W., L. Jimu, M. Marashe and C.A.T. Katsvanga. 2010. Comparative Growth and Yield Responses of Rape (*Brassica napus*) to different Soil Fertility Management Amendments. Electronic J. Environ., Agric. Food Chem. 9: 207-214.

Orozco, F.H. 1996. Vermicomposting of coffee pulp using the earthworm Eisenia fetida: Effects on Carbon and Nitrogen contents and the availability of nutrients. Bio. Fertility of Soils. 22: 162 -166.

Pour, A.A., A.R. Ladan Moghadam and Z.O. Ardebili. 2013. The effects of different levels of vermicompost on the growth and physiology of cabbage seedlings. Int. Res. J. Applied Basic Sci. 4(9): 2726-2729. ISSN 2251-838X

Ravi, S., P.D. Odorico, L. Wang and S.L. Collins. 2008. Form and Function of Grassring Patterns in Arid Grasslands: The Role of Abiotic controls, Oecologia, 158: 545–555.

Roberts, P., D.L. Jones and G. Edwards-Jones. 2007. Yield and Vitamin C Content of Tomatoes Grown in Vermicomposted Wastes. J Sci Food Agric, 87: 1957-1963.

Sahni S, B.K. Sarma, D.P. Singh, H.B. Singh and K.P Singh. 2008. Vermicompost enhances performance of plant growth-promoting rhizobacteria in Cicer arietinum rhizosphere against *Sclerotium rolfsii* and quality of strawberry (Fragaria x ananassaDuch.). Crop Prot. 27: 369–376.

Sharma, R. 2001. Vermiculture for sustainable agriculture: Study of the agronomic lmpact of earthworms and their vermicompost on growth and production of wheat crops. Ph.D. Thesis, submitted to the University of Rajasthan, Jaipur, India.

Sharma, S., K. Pradhan, S. Satya and P. Vasudevan. 2005. Potentiality of Earthworms for Waste Management and in Other Uses – A Review. J. Am. Sci. 1: 1-16.

Sinha, R., K. Hahn, G.P.K. Singh, R.K. Suhane and A. Reddy. 2011. Organic Farming by Vermiculture: Producing Safe, Nutritive and Protective Foods by Earthworms (Charles Darwin's Friends of Farmers). Amer. J. Exp. Agric. 1: 363-399.

Srivastava, P.K, M. Gupta, R.K. Upadhyay, S. Sharma, S. Shikha, N. Singh, S. Tewari and B. Singh. 2012. Effects of combined application of vermicompost and mineral fertilizer on the growth of *Allium cepa* L. and soil fertility. J. Plant Nutr. Soil Sci. 175:101–107.

Svotwa, E., R. Baipai and J. Jiyane. 2009. Organic Farming in the Small Holder Farming Sector of Zimbabwe. J. Organic Sys. 4: 8-14.

The United Nations Convention to Combat Desertification. 2012. Policy Brief Zero Net Land degradation. 2nd ed. Brazil: Ediouro Grafica.

Troeh, F.R. and L.M. Thompson. 1993. Soils and Soil fertility. Oxford University Press, New York.

Zimbawbe Fertiliser Company. 2011. Horticultural Handbook (January) Aspindale Sports Club; Harare.