American-Eurasian J. Agric. & Environ. Sci., 12 (3): 399-406, 2012
ISSN 1818-6769

Effects of Chicken Manure on Growth, Yield and Quality of Lettuce (*Lactuca sativa* L.) 'Taina' Under a Lath House in a Semi-Arid Sub-Tropical Environment

Michael T. Masarirambi, Phiwokwakhe Dlamini, Paul K. Wahome and Tajudeen O. Oseni

Department of Horticulture, Faculty of Agriculture, University of Swaziland, P.O. Luyengo M205, Swaziland

Abstract: Chicken manure is natural, locally available and relatively cheap material that the organic vegetable growers can obtain. Inorganic fertilizers are relatively expensive and can potentially contaminate the environment. Lettuce (*Lactuca sativa* L.) is one of the widely used salad vegetable crops in Swaziland. This experiment was carried out in a lath house at Luyengo Campus, Horticulture Farm, University of Swaziland to assess the effects of varied levels of chicken manure on growth, yield and quality of lettuce. The cultivar used was 'Taina'. The levels of chicken manure used were 60, 40 and 20 t/ha. A control of inorganic fertilizer 2:3:2 (22) + 0.5% Zn was used at a rate of 955 kg/ha basal dressing and limestone ammonium nitrate (LAN 28%) at a rate of 100 kg/ha as side dressing. The results showed that chicken manure levels significantly ($P < 0.05$) affected growth, yield and nutritional quality of lettuce. A trend of superiority of the different level of chicken manure application was observed as lettuce provided with 60 t/ha exhibited higher values in number of leaves, plant height, marketable yield and mean leaf dry mass. The second best results were obtained from plants supplied with 40 t/ha followed by plants previously fertilized with 20 t/ha and the lowest from those provided with inorganic fertilizer. However, there was no significant ($P > 0.5$) difference in iron content on fresh mass basis for all treatments. Results of this experiment showed that inorganic fertilizer was less suitable in lettuce production. Lettuce may be grown using 60 ton/ha chicken manure for a more productive enterprise.

Key words: Chicken manure · Organic production · Yield · Quality · *Lactuca sativa*

INTRODUCTION

Animal manures have been used for plant production effectively for centuries. Chicken manure has long been recognized as perhaps the most desirable of these natural fertilizers because of its high nitrogen content [1, 2]. In addition, manures supply other nutrients and serve as soil amendments by adding organic matter [3-6]. Organic matter persistence in soil will vary with temperature, drainage, rainfall and other environmental factors. Organic matter in soil improves moisture and nutrient retention and soil physical properties [7-9]. The utilization of manure is an integral part of sustainable agriculture [10].

Chicken manure is often produced in areas where it is needed for pastures and crop fertilization. The increased size and frequent clean out of many poultry operations make poultry manure available in sufficient quantities and on timely basis to supply most fertilizer needs [1]. When properly applied, chicken manure can be a valuable resource for grass, small grains and other crop production. The economics of using chicken manure varies considerably. Poultry litter is made out of raw poultry manure and bedding materials such as sawdust, wood shavings, grass cuttings, banana leaves or rice hulls. This combination provide an excellent source of nitrogen (N), phosphorus (P), potassium (K) and sulfur (S) [10].

Lettuce is a native of Europe, Asia and Northern Africa and has been cultivated for over 5000 years [11]. One piece of evidence that support this idea is the existence of a primitive nearly wild form where it was first cultivated. The existence of this form suggests that it originated from wild lettuce most likely *Lactuca serriola* L commonly known as pink lettuce. The second evidence was found on Egyptian tomb painting, dating from the middle kingdom, about 4500 years ago. The stylized paintings appear to be bundles of stems, similar to the type of presently cultivated lettuce in Egypt [12]. Nowadays lettuce is grown all over the world in places of different climatic conditions and soil fertility conditions. Such remarkable distribution requires some degree of technology to adapt to such varied conditions. This is

Corresponding Author: Michael T. Masarirambi, Department of Horticulture, Faculty of Agriculture, University of Swaziland, PO Luyengo M205, Swaziland

why some workers have undertaken research on various aspects of the crop to suite their conditions. There is dearth of information pertaining to organic manure requirements of lettuce in a semi-arid sub-tropical environment as prevailing in many parts of Swaziland.

Lettuce leaves are a rich source antioxidants, Vitamin A and C [13] and phytochemicals which are anti-carcinogenic. Lettuce is usually consumed individually as a salad or shredded in a salad mix of onion, tomato, cheese and basil. It has now caught vegetable grower's attention in the Southern African region since it has increasingly become popular as a salad vegetable [14].

Commercial and subsistence farming has been relying on organic fertilizers for growing crops [1]. This is because inorganic fertilizers are easy to use, are quickly absorbed and utilized by the crop. However in the long run, they destroy the soil structure if they are not used carefully and increase the costs of production resulting in reduction of profit in crop production enterprises. This study will provide information on how varied quantities of chicken manures affect growth yield and quality of lettuce. As long as organic manures are available and comparable with inorganic fertilizers in yield improvements, their use as sources of plant nutrients for growing vegetable crops could assume increasing importance [15]. In the region there is increasing hype of organic vegetable production [16-18]. The continued dependency of Swaziland and other developing countries on inorganic fertilizers has made the price of agricultural commodities to be relatively expensive. Due to high energy costs inorganic fertilizers have become very expensive and also scarce, especially in developing countries [19]. The chemicals used in conventional agriculture contain few minerals, which dissolve quickly in damp soil and give the plant large doses of minerals [11]. This happens just at relatively short period of time and usually more nutrients than are needed by the plant are applied. For example, N from any kind of fertilizer affects the amount of vitamin C and nitrate as well as the quality produced by the plant. Moreover, potassium fertilizers have antagonistic effects on magnesium and directly, the phosphorus content of some plants. Hence conventional crops would contain few amounts of magnesium and phosphorus than organic crops [20]. Inorganic fertilizers also contain toxic heavy metals such as cadmium [21].

Organic fertilizers such as chicken manure can therefore be used to reduce the amount of toxic compounds (such as nitrate) produced by conventional fertilizers. Hence, improving the quality of leafy vegetables produced as well as human health. Also, it will be possible to lessen the escalating effects of disease such as HIV and AIDS and cancer. Besides all these, farm income will improve when farmers use less inorganic fertilizers and pesticides for growing crops. Less use of inorganic fertilizer and pesticides will lessen negative impact on impending permanent climate change.

The specific objectives of the study were to:

- asses the effect of chicken manure and in organic fertilizers on growth of lettuce; and
- determine the feasibility of using different quantities of chicken manure on yield and quality of lettuce.

MATERIALS AND METHODS

Experimental Site: The experiment was conducted in a lath house at the University of Swaziland, Luyengo Campus in the Horticulture Department. This was during the cropping year 2009/2010. The site is located between latitude 26° 58' S and 31°E 18' E and at an altitude of 734 m above sea level. The area receives an average annual precipitation of 980 mm with most of rain occurring between October and April. Hazard of drought is about 40 %. The average winter temperature is about 15 ° C while for summer it is about 27 ° C. The experimental lath house was covered with black net and the percentage shade in the lath house was 37.6.

Media and Fertilizer Analysis: River sand and chicken manure were used. Analyses were conducted to determine the sand and chicken manure's physical and chemical properties [22] at the Malkerns Research station. The physical and chemical properties of the medium (sand) and chicken manure used in the experiment are shown in Table 1. This was used to explore the real effects of the different treatments, since sand is believed to be inert. The sand was obtained from the Usuthu River. Irrigation was done using watering can. The mean application volume of the irrigation water was 1000 cm^3 per pot (plant). This was done in the early hours of the day (between 6 and 7 AM). The trial was weeded manually by pulling weeds from the plots.

Experimental Design: The experiment was laid in a Randomized Complete Block Design (RCBD). It comprised of three treatment and four replications. The gross experimental area was 4 × 17 m (68 m^2) and the net experimental area was 3 × 12 m (36 m^2) each plot dimension

Table 1: Physical and chemical characteristics of the medium (sand) and chicken manure used in the experiment

Texture	pH	Exchangeable acidity meq/100g)	Phosphorus (P) (mg/kg)	Potassium (K) (mg/kg)
Chicken manure	6.3	0.43	1876	1943
Medium (sand)	7.0	0.25	101	134

Table 2: Pot layout in the experimental lath house

Block 1		Block 2		Block 3		Block 4	
40ton/ha	60ton/ha	20ton/ha	Control	60ton/ha	20ton/ha	control	40ton/ha
Control	20ton/ha	60ton/ha	40ton/ha	40t/ha	control	20ton/ha	60ton/ha

were 1.5 × 1.5 m (2.25 m^2) and there were sum of 16 plots. Plant spacing was 30 cm between rows and 30 cm-diameter flower pots were used. The media was filled to ¾ of the volume of the pot. Pot layout in the experimental lath house is shown in Table 2.

Fertilization: There were two types of fertilizers used at basal dressing, i.e. chicken manure and 2:3:2 (22) + 0.5 Zn (control). The chicken manure was applied at different levels which were 20, 40 and 60 t/ha. In the control, 2:3:2(22) + 0.5 Zn was applied only at 955kg/ha at basal dressing. For side dressing of all the treatment, Limestone Ammonium Nitrate (LAN), was used at the rate of 100 kg/ha. Chicken manure was applied a week before planting to ensure microbial activity occurred before transplanting. Side dressing was done 2 weeks after transplanting.

Plant Material: The lettuce cultivar 'Taina' was used. Seeds were obtained from NAMBoard Matsapha, Swaziland. They were germinated and transplanting was performed four weeks after germination.

Data Collection: Data were collected 2 weeks after transplanting and at 1 week intervals. The data collected included the following parameters: plant height, leaf area, leaf area index, marketable yield, shoot-root ratio and the nutrient composition of fresh lettuce (leaf tissue analysis). All data were collected on five plants selected randomly from each plot.

Mineral Content Analysis of Leaf Tissue: A microwave was used for digestion of lettuce plant tissue. A sample of 0.5 g of each treatment was weighed and put in the microwave bomb [23]. For calcium (Ca) analysis, 10 ml 6M HCl and 10 ml 6M HNO_3 was used for digestion. For iron (Fe) analysis, 10 ml H_2SO_4 and 10 ml 6M HNO_3 were used for digestion. The acids were added into the bombs containing the samples and digested in the microwave for two minutes. The samples were then cooled to room temperature and filtered into 50 ml volumetric flasks. Dilution to the mark was done using deionized water.

Table 3: Operating parameters for AAS

Parameter	Fe	Ca
Wave length (khz)	243.6	421.1
Slit width (nm)	2.0	0.5
Lamp current (mA)	30	10

Standard solutions of 0.5 ppm, 1.0 ppm, 1.5 ppm and 2.0 ppm were prepared from a 1000 ppm stock solution of Ca and Fe using the formula: $C_1V_1 = C_2V_2$. With a known concentration (C_2) and volume (V_2) required, the volume of 1000 ppm stock solution was calculated and made necessary dilutions to make V_2. Standards were run in the atomic absorption spectrometer (AAS) to determine their absorbance from which calibration curves were plotted. The operating parameters for AAS are shown (Table 3).

Data Analysis: The data collected were analyzed using MSTAT-C statistical package [24], Analysis of variance (ANOVA) was undertaken on the data collected so to determine if there were significant differences amongst treatments. Mean separation was done using the Duncan's New Multiple Range Test (DNMRT) where significant differences existed [25].

RESULTS

Plant Height: The results showed significant ($P<0.05$) differences in growth amongst treatments. The highest plants were obtained from lettuce provided with 60 t/ha chicken manure (Fig. 1). Plant height decreased with each decrease in level of chicken manure. The lowest plant height was obtained from lettuce supplied with inorganic fertilizer.

Number of Leaves: The average number of leaves per plant was significantly ($P< 0.05$) different across all treatments. The highest number of leaves was obtained from lettuce provided with 60 t/ha chicken manure (Fig. 2). Number of leaves decreased with each decrease in level of chicken manure applied. The lowest number of leaves was obtained from lettuce supplied with inorganic fertilizer.

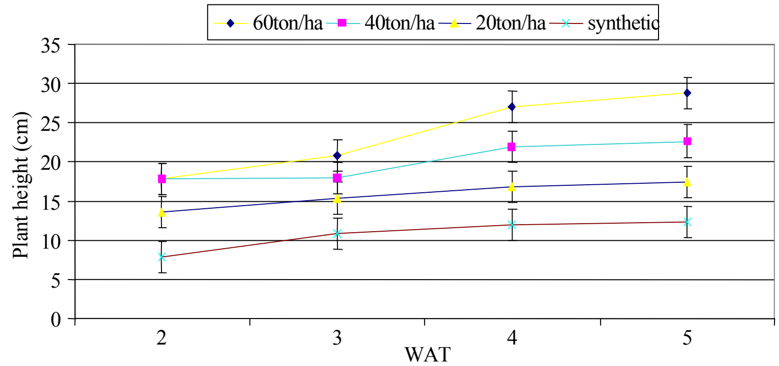

Fig. 1: Plant height of lettuce (*Lactuca sativa*) as affected by different levels of chicken manure and inorganic fertilizer. Bars represent standard error (SE) below and above the mean

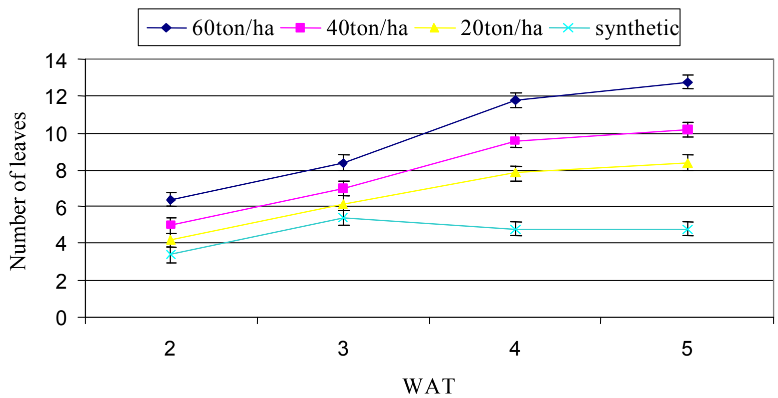

Fig. 2: Number of leaves of lettuce (*Lactuca sativa*) as affected by different levels of chicken manure and inorganic fertilizer. Bars represent (SE) below and above the mean

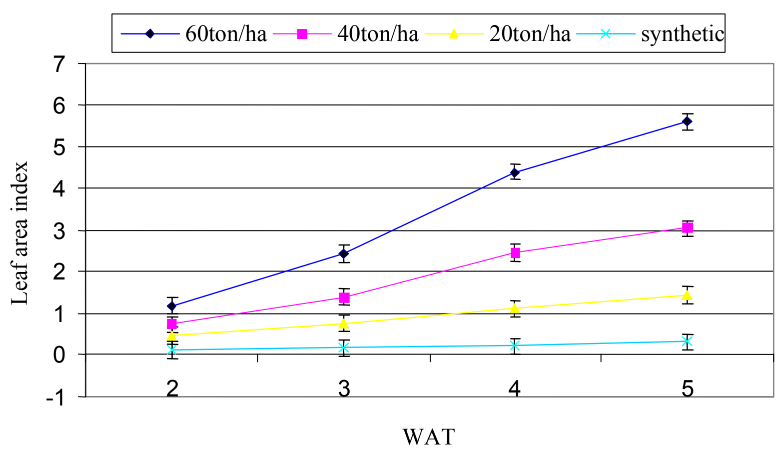

Fig. 3: Leaf area index of lettuce (*Lactuca sativa*) as affected by different levels of chicken manure inorganic fertilizer. Bars represent (SE) below and above the mean

Leaf Area Index: Significant ($P<0.05$) differences were recorded in leaf area index (LAI) among treatments. The highest leaf area index was obtained from lettuce provided with 60 t/ha chicken manure (Fig. 3). The lowest leaf area index was obtained from lettuce supplied with organic fertilizer.

Yield Parameters: Different levels of manure applications behaved differently in terms of harvest parameter as was shown by the significant ($P<0.05$) differences in marketable yield, dry matter and shoot-root ratio. The highest marketable yield (Fig. 4), dry matter (Fig. 5) and shoot-root ratio (Fig. 6) was obtained from lettuce

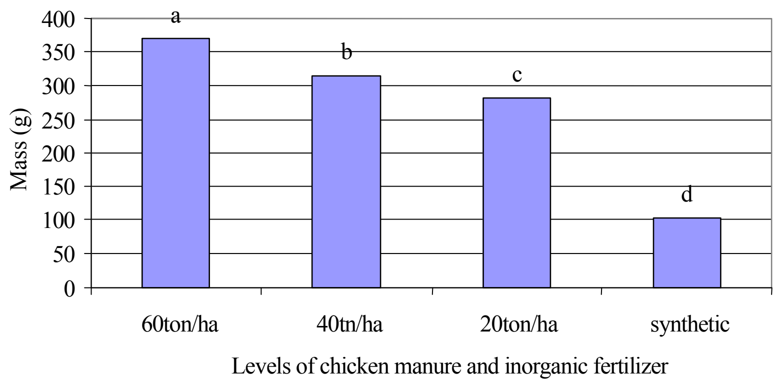

Fig. 4: Marketable yield of lettuce *(Lactuca sativa*) as affected different levels chicken manure and inorganic fertilizer. Treatments with different letters are significantly different at $p < 0.05$

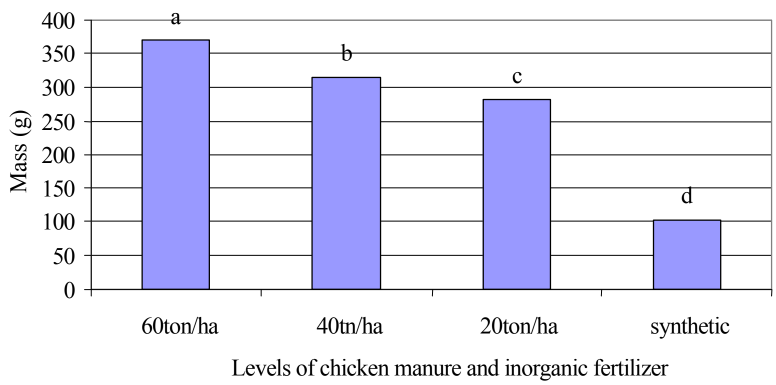

Fig. 5: Dry mass of lettuce (*Lactuca sativa*) as affected different levels chicken manure and inorganic fertilizer. Treatments with different letters are significantly different at $p < 0.05$

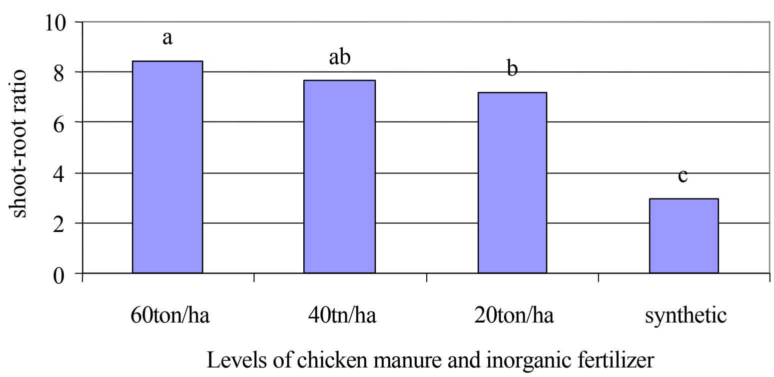

Fig. 6: Shoot-root ratio of lettuce (*Lactuca sativa*) as affected by different levels chicken manure and inorganic fertilizer. Treatments with different letters are significantly different at $p < 0.05$

provided with 60 t/ha chicken manure. Marketable yield and dry matter decreased with each decrease in level of chicken manure application. The lowest marketable yield and dry matter were obtained from lettuce supplied with inorganic fertilizer.

Quality (Calcium, Iron): There were significant ($P<0.05$) differences in calcium content in the fresh samples of lettuce among treatments. The highest calcium contents was obtained from lettuce provided with 60 t/ha chicken manure (Fig. 6). Calcium content was decreased with each decrease in level of chicken manure application. The lowest calcium content was obtained from lettuce supplied with inorganic fertilizer. However, there was no significant ($P> 0.01$) different in iron content for all the treatments (Fig. 7). The Fig. 7 has been included to show trends of the trace element.

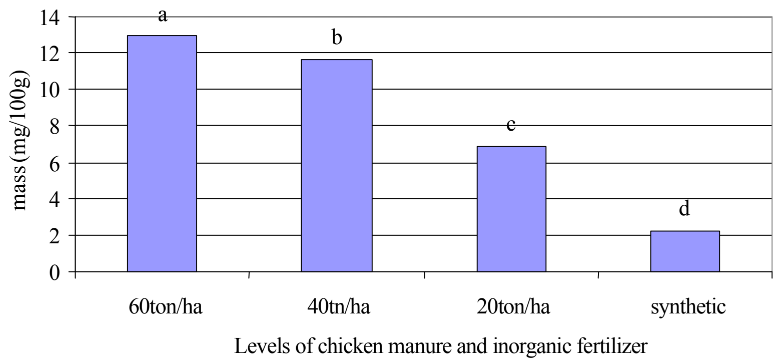

Fig. 7: Calcium content of lettuce (*Lactuca sativa*) as affected by different levels of chicken manure and inorganic fertilizer. Treatments with different letters are significantly different at $p < 0.05$

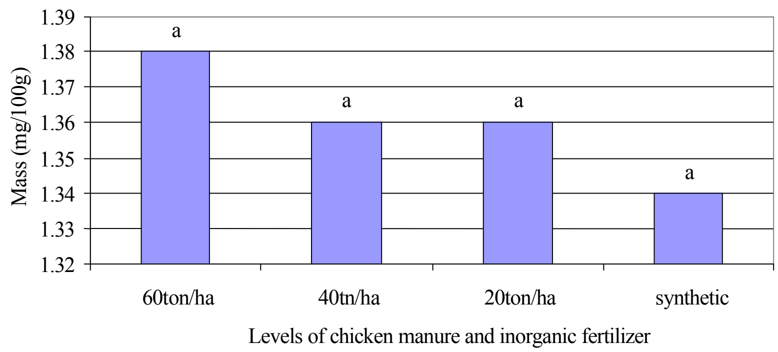

Fig. 8: Iron content trends of lettuce (*Lactuca sativa*) as affected different levels of chicken manure and inorganic fertilizer. Treatments with the same letter are not significantly different at $p > 0.05$.

DISCUSSION

There were significant ($P<0.05$) differences in growth, marketable yield and quality of lettuce at 2, 3, 4 and 5 WAT. These depended on the level of chicken manure applied. Plants which had been fertilized by higher levels of chicken manure (60 t/ha > 40 t/ha) exhibited higher yields than those applied with lower level, this could be attributed to large quantities of available phosphorus and available potassium per kilogram in the manure (Table 3). Studies by Rao [26] showed that the soil could be enriched by application of higher amounts of organic materials which tends to decompose large amounts of nitrogen into the soil before planting each fresh crop to boost yield. The quantity of application of organic fertilizer has effects on crop yield and nutrient uptake. Another study by Xu *et al*. [27] showed that vegetables grown with higher levels of organic manures grew better and resulted in a final higher total yield than those grown on lower amounts together with those grown using synthetic fertilizers. Therefore, this study has established that lettuce grown on higher level of chicken manures showed higher growth and yield than that grown on lower level of chicken manure and synthetic manure. Generally, these results are in agreement with those reported by USDA [28]; Xu *et al*. [27, 2, 6].

This study had also established that inorganic fertilizers performed inferiorly as compared to the chicken manure in the production of lettuce. This can be attributed to the lower esteem in retention of moisture that is exhibited by inorganic fertilizers as postulated by Owen [29],who reported that synthetic fertilizers do not have good characteristics in aggregating soil particles. As a result, the plants produced by inorganic fertilizer produced relatively lower yield than those supplied with chicken manure. This is coupled with the known beneficial effects of animal manure on physical and chemical properties [30] and their ability to supply macro- and trace elements not contained in the inorganic fertilizers [31].

Considerable variations in leaf dry matter of lettuce were observed amongst the treatments. Higher levels of chicken manure application had higher leaf dry matter while the one treated with synthetic fertilizer had the lowest. Similarly increased growth and yield of two cultivars of cantaloupe (*Cucimis melo*) were reported with increased application of broiler litter [2]. Magkos *et al*. [32] established that vegetables cultivated on soils with higher amounts of organic fertilizers had higher dry matter as compared to those produced conventionally. These findings however were evident only for plants that grow above the ground, more especially leafy vegetables such as spinach, lettuce, chard, savoy cabbage and white cabbage [32]. Therefore, this study outcome supported what was gathered by Magkos *et al*. [32].

Based on 100 g edible product of lettuce, fertilization had significant effects in calcium content of the lettuce. This can be attributed to relatively ample amounts of calcium in the chemical composition of chicken manure. Higher levels of manure had higher levels of calcium content as compared to lower levels. Similar results have been reported previously in broccoli [6] and in lettuce [18]. In that study of Masarirambi *et al*. [18], lettuce fertilized by bounce back compost was higher in calcium, iron and zinc contents on fresh mass basis while plants fertilized by cattle manure followed and then inorganic fertilizer and lastly chicken manure [18].. However, levels of application had no significant effects on iron content of the lettuce. Magkos *et al.* [32] reported that although a small number of studies have been published, slightly higher contents of minerals such as iron, calcium, phosphorus, magnesium, manganese, zinc, copper and potassium have been obtained in organic vegetables; most of the evidence, however revealed no significant difference between organic and inorganically grown vegetables. Worthington [20] reported similarly. Up to now the jury is out there deliberating as to which vegetables are more nutritious i.e. organically or conventionally grown?

The use of animal manures has had some negative side effects like transmission of human pathogens such as *Escherichia coli* in lettuce [33-36]. Such negative side effects of animal manure may be avoided by appropriate treatment of manure prior to use. Treatments such as pasteurization and composting can be done at not much additional cost. The benefits versus costs of animal manure use in vegetable production far outweigh the negative effects in this era of impending permanent climate change considering that inorganic fertilizer production is associated with production of negative externalities such as green house gases.

CONCLUSION

Lettuce grown in a sand medium amended with relatively higher amounts of organic manures exhibited more vigorous growth (number of leaves, plant height and leaf area index) and yield (marketable yield) than those with lower levels together with those grown with organic fertilizers. Lettuce grown in larger quantities of chicken manure showed relatively higher amounts of calcium; however there were no differences in iron content in the lettuce.

Based on the results and conclusions drawn from the research, the following suggestions can be made:

- Lettuce can be grown using 60 t/ha chicken manure, for higher yield and quality.
- Further study on even higher levels of chicken manure should be carried out.

REFERENCES

1. Eliot, F., 2005. Organic Farming in Scotland. http://www.alfredhartemink.nl/fertilizer.htm, (21/09/2009)
2. Ghanbarian, D., S. Youneji, S. Fallah and A. Farhadi, 2008. Effect of broiler litter on physical properties, growth and yield of two cultivars of cantaloupe (*Cucumis melo*). Int. J. Agric. Biol., 10: 697-700.
3. Bin, J., 1983. Utilization of green manure for raising soil fertility in China. Soil Sci., 135: 65-69.
4. Pervez, M.A., F. Muhammad and E. Ullah, 2000. Effects of organic and inorganic manures on physical characteristics of potato (*Solanum tuberosum* L.). Int. J. Agric. Biol., 2: 34-36.
5. Dauda, S.N., F.A. Ajayi and E. Ndor, 2008. Growth and yield of water melon (*Citullus lanatus*) as affected by poultry manure application. J. Agric. Soc. Sci., 4: 121-124.
6. Ouda, B.A. and A.Y. Mahadeen, 2008. Effects of fertilizers on growth, yield, yield components, quality and certain nutrient contents in Broccoli (*Brassica oleracea*) Int. J. Agic. Biol., 10: 627-632.
7. Zane, F.L. and D.D. Basil, 1980. Residual effects of dairy cattle manure on plant growth and soil properties. Agron. J., 72: 123-130.
8. Stamatiadis, S., M. Werner and M. Buchanan, 1999. Field assessment of soil quality as affected by compost and fertilizer application in a broccoli field (San Benito County, California). Appl. Soil Ecol., 12: 217-225.
9. Arisha, H.M. and A. Bradisi, 1999. Effect of mineral fertilizers and organic fertilizers on growth, yield and quality of potato under sandy soil conditions. Zagazig J. Agric. Res., 30: 1875-1899.
10. Anonymous, 2008. Organic Farming as a Sustainable Vegetable Production to Provide Better Vegetable Quality. htt://www.actahort.org/book/604/604_52.htm(22/09/2009).

11. Vernon, G., 1999. Sustainable Vegetable Production. Ithca Inc. New York. USA.
12. Rhodes, D., 2004. Allergiesof Lettuce. htt://dermnetnz.org/dermatitis/plants/lettuce.html (20/09/209)
13. Norman, J.C., 1992. Tropical Vegetable Crops. Stockwell LTD. Illfracombe. United Kingdom.
14. Maboko, M.M. and C.P. Du Plooy, 2008. Evaluation of crisp head lettuce cultivars (*Lactuca sativa* L.) for winter production in a soilless production system. African J. Plant Sci., 2(10): 113-117.
15. Ogunlela, V.B., M.T. Masarirambi and S.M. Makuza, 2005. Effects of cattle manure application on pod yield and yield indices of okra (*Abelmoschus esculentus* L. Moench) in a semi-arid sub-tropical environment. J. Food Agric Environ., 3: 125-129.
16. Kantashula, E., G. Sileshi, P.L. Mafongoya and J. Banda, 2006. Farmer participatory evaluation of the potential for organic vegetable production in the wetlands of Zambia. Outlook. Agric., 35(4): 299-305.
17. Van Averrbeke, A. and S. Yoganathan, 2003. Using Kraal Manure as Fertilizer. Department of Agriculture. Pretoria. South Africa.
18. Masarirambi, M.T., M.M. Hlawe, O.T. Oseni and T.E. Sibiya, 2010. Effects of organic fertilizers on growth, yield, quality and sensory evaluation of red lettuce (*Lactuca sativa* L.) 'Veneza Roxa'. Agric. Biol. J. North America, 1(6): 1319-1324.
19. Williams, L.B. and G. Harris, 1986. Fertilizer marketing in Nigeria. Fert, Int., 225: 45-49.
20. Worthington, V., 2001. Nutritional quality of organic versus conventional fruits, vegetables and grains. J. Alternative Comp. Med., 7: 161-173.
21. White, R.E., 2006. Principles and Practices of Soil Science. Fourth Edition. Blackwell Publishing, Oxford. United Kingdom.
22. A.O.A.C., 1984. Official Methods of Analysis. 14th Edition. Association of Official Analytical Chemists, Washington D.C., USA.
23. Microsoft® Encarta® Encyclopedia, 2003. © 1992-2002. Microsoft Cooperation.
24. Nissen, O., 1989. MSTAT-C. A Micro-computer Program for the Design and Management and Analysis of Agronomic Research Experiments. Michigan State University. East Lansing. Michigan, USA.
25. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Edition. John Wiley and Sons. Singapore.
26. Rao, M.K., 1991. Textbook of Horticulture. University of Madaras. Madaras, India.
27. Xu, H.L., R. Wang, R.Y. Xu, M.A.U. Mridha and S. Goyal, 2005. Yield and quality of leafy vegetables grown with organic fertilizations. Acta Hort, 627: 25-33.
28. United States Department of Agriculture (USDA), 1979. Animal Waste Utilization on Cropland and Pstuerland. USDA Utilization Report No, 6.
29. Owen, P., 2008. Origin and Distribution of Lettuce. http://www.calettuceresearchboard.org/Origin.html (14/02/2010).
30. Aliyu, L., 2000. Effect of organic and mineral fertilizers on growth, yield and composition of pepper (*Capsicum anuum* L.). Biol. Agric. Hort., 18: 29-36.
31. Mbagwu, J.S.C. and G.C. Ekwealor, 1990. Agronomic potential of brewr's spent grains. Biol. Wastes, 34: 335-347.
32. Magkos, F., F. Arvaniti and A. Zampelas, 2003. Organic food: Nutritious food or food for thought? A review of evidence. Int. J. Food Sci. Nutri., 54: 357-371.
33. Johannessen, G.S., R.B. Frøseth, L. Solemdal, J. Jarp, Y. Wasteson and L.M. Rørvik, 2004. Influence of bovine manure as fertilizer on the bacteriological quality of organic Iceberg lettuce. J. Appl. Microbiol., 96: 787-794.
34. Ackers, M.L., B.E. Mahon, E. Leahy, B. Goode, T. Damrow, P.S. Hayes, W.F. Bibb, D.H. Rice, T.J. Barrett, L. Hutwagner, P.M. Griffin and L. Slutsker, 1998. An outbreak of Escherichia coli O157:H7 infections associated with leaf lettuce consumption. J. Infect. Dis., 177: 1588-1593.
35. Hilborn, E.D., J.H. Mermin, P.A. Mshar, J.L. Hadler, A. Voetsch, C. Wojtkunski, M. Swartz, R. Mshar, M.A. Lambert-Fair, J.A. Farrar, K. Glynn and L. Slutsker, 1999. A multistate outbreak of Escherichia coli O157:H7 infections associated with consumption of mesclun lettuce. Arch. Intern. Med., 159: 1758-1764.
36. Islam, M., M.P. Doyle, S.C. Phatak, P. Millner and X. Jiang, 2004. Persistence of enterohemorrhagic Escherichia coli O157:H7 in soil and on leaf lettuce and parsley grown in fields treated with contaminated manure composts or irrigation water. J. Food Prot., 67: 1365-1370.