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Impact of Poultry Manure and its Associated Salinity on the Growth and Yield of Spinach (*Spinacea oleracea*) and Carrot (*Daucus carota*)

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ABSTRACT

This study was conducted to assess the effects of poultry manure and its associated salinity on the yield of spinach and carrot. Samples from three textural distinct soils Calcisol, Arenosol and Luvisol were mixed with poultry manure (at 5, 10, 20 & 40% manure application rate) into equally sized pots. After three weeks following germination, the spinach and carrot seedlings were transplanted in these mixed samples, watered and monitored until the crops reached maturity. Data regarding the yield and related traits such as shoots length, area of the edible part, fresh and dry biomass were recorded during the course of experimentation. There was substantial decrease in both crops' shoot length with increasing application rate up to 20% rate and virtually no growth observed in the 40% treatment suggesting the adverse effects of poultry manure on plant yield. Similarly, poultry manure induced the salinity of the samples with reduction in crop yields. Carrots were more severely affected (with virtually no growth observed even in the addition of 5% manure) because of its high sensitivity. Irrespective of the treatments, Arenosols yielded best results than other soil types, while spinach crop performed better than carrots probably due to the high sensitivity of carrot to salinity. © 2010 Friends Science Publishers

Key Words: Poultry manure; Salinity; Spinach *(Spinacea oleracea)* and Carrot *(Daucus carota)*

INTRODUCTION

The use of poultry manure in promoting organic farming and in enhancing soil fertility has profound implications in the agricultural production, as well as socio-economic status of rural livelihoods in the developing world. For example, in Botswana the agricultural sector provides the bulk of the national labour force (CSO, 2001), despite its low Gross Domestic Product contribution (4%; NAMPADD, 2000; CSO, 2001). Poultry manure has frequently been found to increase the yields of pastures and crops including vegetables (Edwards & Daniel, 1992). Vegetables are vital components of health diet and hence a need to produce vegetables to support human life. In particular green leafy vegetables (e.g., spinach) and yellows (e.g., carrot) provides essential minerals and vitamins A, E and C. Maintenance and management of soil fertility is central to the development of sustainable food systems (Prasad & Power, 1997). Moreover, soil fertility replenishment in the Sub-Saharan Africa (SSA) is increasingly viewed as critical to the process of poverty alleviation even if the per capita arable land in SSA has shrunk from 0.53 to 0.35 ha between, 1970 and 2000 (FAOSTAT, 2002). In addition poultry manure provides socio-economic enlistments as some city dwellers sells manure for their living income. In Botswana, until recently, poultry waste has been sold to individuals and farmers to use it as manure especially in the city of Gaborone as evidenced by increased sale of bags of poultry manure along major roads.

The suitability of soils to producing vegetables depends on fertilizer application rate as well its fertility status including organic matter, inorganic matter, air and water. Poultry manure as an organic material is particularly important since it conditions and improves soil fertility and contains all macro-nutrients and most of the micro-nutrients (Warman, 1986; Duncan, 2005). Similarly compost and/or biofertilizers have beneficial effects on plant growth and dry matter yield due to hormonal stimulation of root development and by supplying combined nitrogen (Gharib *et al.,* 2008). Organic matter in the soil stimulates the activity of the micro-organisms to convert nutrients in manure and soil particles into a suitable form for plants uptake. However, damage to crops and pasture (Edwards & Daniel, 1992) were reported, when poultry manure is applied at high rates (>18 t/ha). Similarly high application rate of poultry manure (180 t/ha) to a loamy sand was reported to increase the concentration of nitrate at 3 m depth from 15 to 179 mg N/L (Liebhardt *et al*., 1979) and an increased concentrations of nitrate at 120 cm depth in a silt loam soil (Adams *et al*., 1994). Spinach generally grows well in warm conditions and often tolerates frost thus can grow throughout the whole year. A slightly acid sandy loam with a pH between 6.6 and 6.8, is best suited to spinach growth, although spinach can grow well on a wide range of soils (Van Antwerpen & Aves, 2000; Bok *et al.,* 2006). For a long harvesting season with a good quality crop, heavy applications of organic fertilizer are needed. Alternatively, poultry manure can be added at a rate of 2-4 kg m^{-2} for spinach (Bok *et al.,* 2006). On the other hand, carrots require a deeply cultivated, loose, well-drained, sandy loam soil to produce well shaped smooth roots (Van Antwerpen & Aves, 2000; Bok *et al.,* 2006). Unlike spinach, carrots do not require a lot of organic matter or nitrogen. For instance if too much organic matter is present, the roots become forked and crooked and have a rough skin (Bok *et al.,* 2006). Inappropriate application of poultry manure to soil can therefore damage roots and possibly kill plants.

Further application of poultry manure as a fertilizer into soil enhances concentration of water soluble salts in soil. While plants absorb plant nutrients in the form of soluble salts, excessive accumulation of soluble salts (or soil salinity) suppresses plant growth. Stephenson *et al.* (1990) found the EC of poultry manure to be about 11 dS m^{-1}, too high for both carrots and spinach since they are very sensitive and moderately sensitive to salinity, respectively. Salinity can affect plants in three pathways. Initially, salt makes it more difficult for plants to withdraw water from the soil, even if the soil appears quite moist. In essence, the plant experiences a form of drought, which can result in retarded growth and reduced yield.

Similarly, some salts such as Na^+ and Cl^- can be directly toxic to plants. Plants take up salts with the water that they use and often these salts can damage the plant internally thus affecting the plant's physiological processes and often with reduced growth, leaf burn and even plant death. Consequently high amounts of ions such as Na^+ and Cl^- may affect the availability of other ions e.g., K^+, Mg^{2+}, N or P, which are extremely important for plant growth. Generally, a retardation of plant growth as evidenced by a reduction in plant height and/or in the number of leaves or shoots are indicative of plant's first response to salinity. As the plant becomes more affected, it may appear wilted, despite a moist soil and the leaves may show leaf burn (Blaylock, 1994). Shoots are generally more inhibited in growth than roots and even at low salinity levels, root growth may be retarded. Under these more severe circumstances, the plant may die.

The objective of the study was to assess the impact of poultry manure application rate on the yield of spinach *(Spinacea oleracea)* and carrot (*Daucus carota*) in three different soil types. An attempt was also made to evaluate the effectiveness of poultry manure on soil salinity consequently crop yields.

MATERIALS AND METHODS

Study site description: The experimental soil samples were collected from the Glen valley horticultural farms near Gaborone, Botswana. The area is semi-arid, characterized by annual rainfall amounts between 400 and 500 mm and an annual average temperature of about 20.6ºC. The mean annual relative humidity is about 56.3%, with monthly averages between 40% in September and 60% in April. Soils occur on a gentle slope of between 0.3 and 2%, gradually decreasing from the southwest to the northeast at an elevation ranging between 960 and 978 m above mean sea level. The soils were classified Vertic Cambisol, Luvic Calcisol and Ferralic Arenosol (FAO, 1988) with the following textural classes; clay loam to clay, sandy loam and sand, respectively.

Sample preparation and greenhouse pot experiments: Soil samples were collected (from study site) randomly at a depth of 0-50 cm, which constitute the rooting zone of the vegetable crops. The soil samples were mixed with chicken manure (on weight basis) at the following application rates or treatments: 5, 10, 20 and 40% poultry manure. The experiments were conducted for three texturally distinct soils; Calcisols, Arenosols and Luvisols for the above treatments (in 3 replicates). Control samples (i.e., 0% poultry manure) were also prepared and together with mixed samples were homogenized and transferred into equal sized pots for the Greenhouse experiment monitoring. Each plant pot was kept moist until the spinach and carrot seedlings were planted. Germination was activated in the spinach and carrot seeds on a damp or moist tissue paper and placed in the oven for about 30 h at an optimum temperature of 2^oC to ensure uniform germination. The seeds showing early signs of germination were directly seeded into the plant pots. Eight seeds were sown in each pot and thinning was carried out when shoots are about 5 cm tall leaving only the most viable shoots. Three relatively healthy shoots (which were evenly spaced in the pots) of spinach and carrots were allowed to grow to maturity in each pot. The crops were watered (as per specific crop water requirements) to field capacity until the end of growth period. To account for physiological processes during growth stages, the spinach and carrot crops were grown, watered and harvested at appropriate times (Table I).

At maturity both crops were frequently watered at a rate of 35-42 mm (1 mm = 1 L of water/m^2 of growing crop). The experimental plots were kept free of weeds (manually weeded) throughout the monitoring. Soil and soil-chicken manure samples were analysed using standard methods (Chescheir *et al.,* 1986; Van Reewijk, 1993; Okalebo *et al.,* 1993) to characterize chicken manure and basic soil properties including pH, EC, exchangeable bases (Table II).

Plant yield analyses: The plant yields from each treatment were evaluated in terms of area edible parts (the leaves & roots), shoot length and biomass (fresh & dry) and were measured in 3 replicates. The shoots length was measured using a 30 cm ruler and the growth rate (cm/week) were monitored every week until maturity stage. Three leaves of plants were sub-sampled from each pot to determine leaf area (cm^2/plant). Each leaf was spread on a flat grid (graph paper) measuring 1 cm x 1cm and the number of grids covered by the leaf were counted and recorded as the leaf area in cm^2. The fresh and dry biomass of spinach (g/plant) was also determined. The leaves of each plant shoots were weighed and recorded as the fresh biomass, while leaves (in pre weighed paper sampling bags) were dried in an oven at 40ºC for at least 48 h to a constant weight to determine the plant dry biomass.

Statistical analysis: Data collected were analyzed using ANOVA to compare means for each treatment at 5% level of significance (using SPSS statistical package program). The Kendall correlation co-efficient was used to analyze and the relationship between the application rate of poultry manure and the yield components and the statistical difference by student T-test (α =5%).

RESULTS AND DISCUSSION

Yield and Growth Components of Spinach

Shoot length and growth: The means of the growth and yield components (for each treatment) were not statistically different ($P > 0.05$) from each other. There was virtually no growth observed in the soil samples treated with 40% poultry manure suggesting the adverse effects of poultry manure on plant yield above 40% application rate. Generally growth rate as measured by shoot length decreases significantly ($p>0.05$) with increasing application rate upto 20% (Fig. 1). In view of the above, there is a slight departure in the case of Luvic Calcisols (Fig. 1a), where the shoots in un-treated soil grew faster than the shoots in treated soils in the initial stage of growth (weeks 1-3) attributable to the adaptation of shoots to the new environment (presence/addition of poultry manure). In subsequent growth stages, in particular the maturity stage, the growth of shoots or plant height were found to decrease significantly with increasing application rate for all soil types (Fig. 1) suggesting the negating impacts of application rate of poultry manure on the spinach growth. This is in contrast to other studies (Davis *et al.*, 2006; Ouda & Mahadeen, 2008), though they mixed poultry manure with inorganic fertilizers.

Leaf area: Similarly the area of the leaves of spinach varied with the application rate and the soil type. The growth (leaf area) increases initially until reaching optimum growth at rates of 10%, 5% and 1% for Calcisol, Arenosol and Luvisol, respectively (Fig. 2). However the leaf area decreased after these threshold values and subsequently decreased to 0 cm^2/plant at 40% poultry manure application rate. The area was significantly increased ($p < 0.05$) by addition of chicken manure except for Vertic Luvisols where the yield was significantly decreased by poultry manure addition. The increase in yield observed is consistent with the studies by several previous studies (Jamil *et al.,* 2004; Davis *et al.,* 2006; Ouda & Mahadeen, 2008). The highest increase in area was recorded in Luvic Calcisols at 40% application rate with 45.86 cm^2/plant/leaf from 12.35cm^2/plant. Ferralic Arenosols recorded an increase from 16.86 cm^2/plant to 27.67 cm^2/plant. The lowest decrease for Vertic Luvisols was from 20.7 cm^2/plant to 4.2 cm^2/plant at 20% manure.

Table I: Physiological characteristics and management of spinach and carrots

Characters	Spinach	Carrot
Planting date	13 April 2009	13 April 2009
Maturation period	63 days (9 weeks)	91 days (13 weeks)
Water requirements and scheduling	Watered frequently, 3 times a week	Watered frequently, 3 times a week

Table II: Characteristics of poultry manure and basic soil properties of selected soil types

Soil type	pH (H_2O)	EC (mS/cm)	Exchangeable bases(cmol/kg)				Nutrients (mg/kg soil)	
			Na	K	Mg	Ca	N	P
Luvic Calcisol	7.38a	0.44a	0.21a	0.08a	0.39a	5.81a	350a	17.6a
Ferralic Arenosol	6.59b	0.06b	0.25b	0.11b	0.06b	1.47b	771b	44.5b
Vertic Luvisol	5.80a	0.19c	0.17c	0.04c	0.14c	2.44c	665c	52.8c
Poultry manure	7.29d	19.74d	0.84d	1.51d	0.63d	9.79d	5,954d	10,490d

Values with the same letter in each column are not significantly different ($P>0.05$) from each other

Table III: Carrot yield for the three different soil types

Soil type	Area of roots (cm^2/plant)	Fresh biomass (g/plant)	Dry biomass (g/plant)
Luvic Calcisol	2a	0.61a	0.050a
Ferrallic Arenosol	4b	1.22b	0.181b
Vertic Luvisol	3c	0.63ac	0.053ac

Values with the same letter in each column are significantly different ($P>0.05$) from each other

Biomass (fresh & dry): As expected the fresh biomass was proportionally higher than the dry biomass of spinach. The trend for wet biomass and dry biomass was different from that of area. There was a significant increase ($p < 0.05$) in biomass only in Luvic Calcisols and significant decrease ($p>0.05$) in biomass for Ferralic Arenosols and Vertic Luvisols as the application rate of poultry manure increased. When the Kendall correlation co-efficient was applied ($r = 6$) it was that there negative correlation ($S=5$) for Ferralic Arenosols and Vertic Luvisols. Optimum biomass was attained at rates of 10%, 5% and 0% for Calcisol, Arenosol and Luvisol, respectively (Fig. 3). In contrast, Jamil *et al.* (2004) reported an increased yield and its components with increasing rates of organic waste over a control. Subsequent application of poultry manure above 40% resulted in virtually no biomass.

Yield and growth components of carrot: Interesting (with the exception of control treatment), there was no plant growth observed in the mixed samples for all soil types, where the emergent seedlings died shortly. This decrease was significant since no yield was recorded with addition of poultry manure. When the Kendall correlation co-efficient was applied ($r = 6$) it was that there negative correlation

Fig. 1: Growth (or plant height) of spinach shoots in the different treatments for different soil types

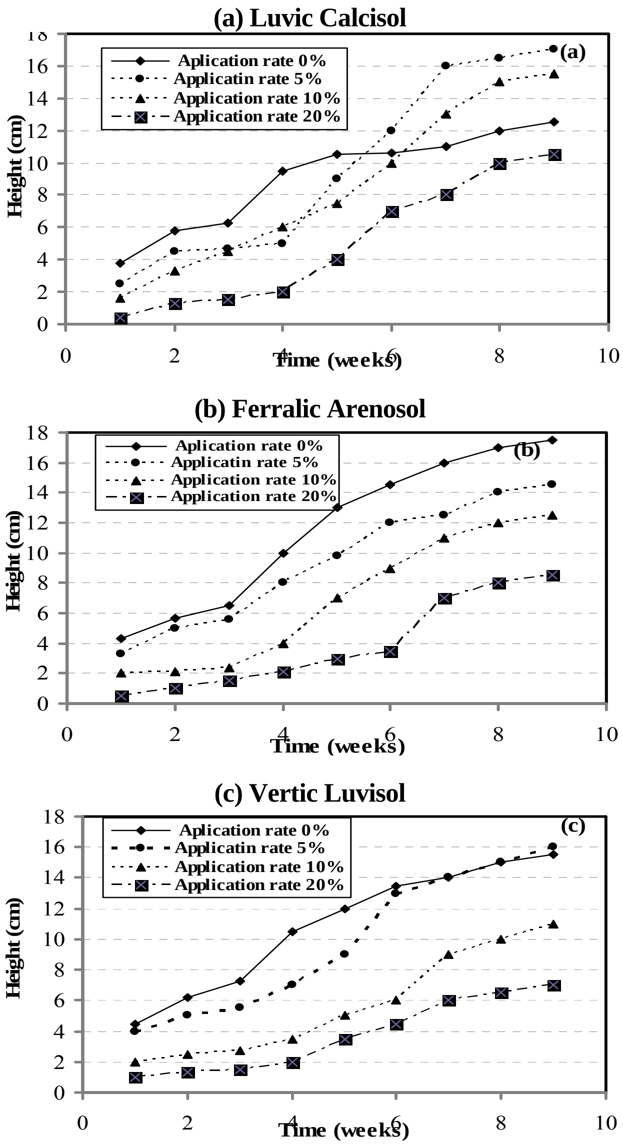
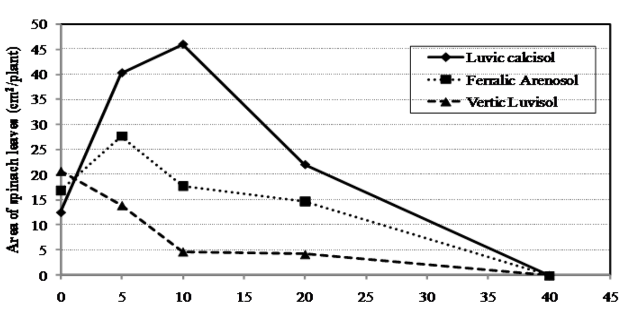


Fig. 2: Effect of application rate on area of spinach leaves for the different types of soils



(S=10) and this is statistical evidence for this decrease. This could suggest the adverse effects of poultry manure on the

Fig. 3: Biomass of spinach for the different soil types

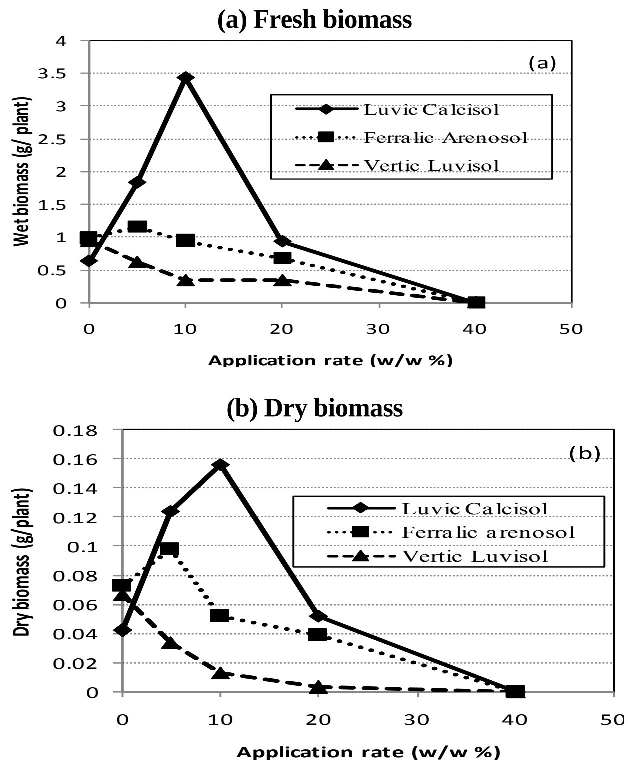
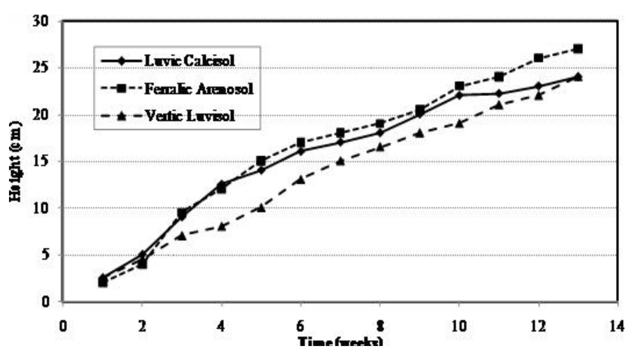


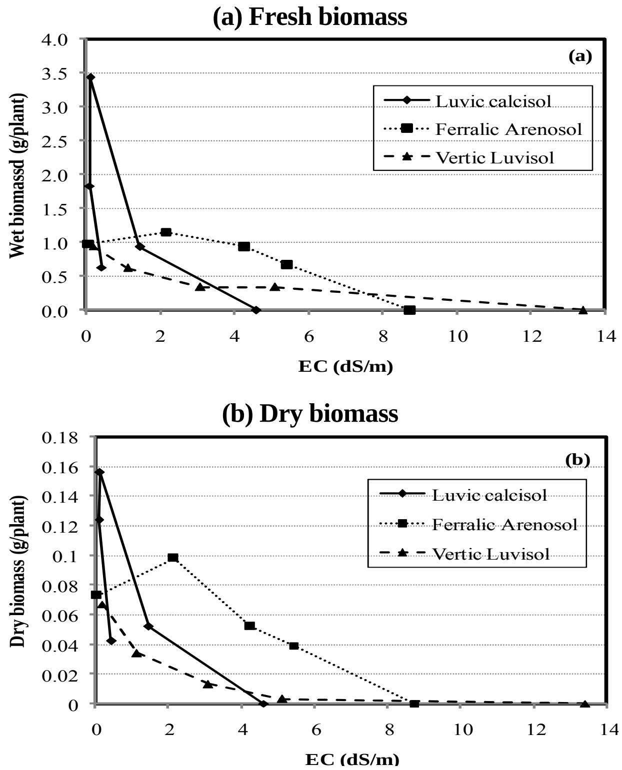
Fig. 4: Growth rate of carrot shoots for selected soils



yield of spinach. The results and discussion for carrot were therefore limited to the control treatment (0% w/w application rate). Generally the growth rate (plant height vs time) of carrot shoots like in spinach was proportionally higher in Ferralic Arenosols than in other soils (Fig. 4). Similar trends were observed for other yield components such as roots area, fresh and dry biomass (Table III) suggesting the biophysical productivity of Ferralic Arenosols in the production of carrots. For instance, the roots area was 4, 2 and 3 cm^2/plant in Luvic Calcisol, Ferralic Arenosol and Vertic Luvisol, respectively.

Vegetable yield associated with the salinity of poultry manure: Soil salinity has profound implications to soils productivity because of adverse effects of EC on the yield (Blaylock, 1994; FAO/RNE, 2003) and as well as fertility of soils. The EC (or salinity) of soils prior to treatments are

Fig. 5: Effect of salinity (or EC) on spinach yield



virtually very low and lower than the critical threshold value of 4 mS cm^{-1} (Table II). On the other hand, the EC of poultry manure is relatively higher (EC =19.7 mS cm^{-1}), consistent to other studies (e.g., Stephenson *et al.,* 1990; Gharib *et al.,* 2008), to significantly pose salinity problem. The critical threshold value of EC for the sustenance of vegetable crops is 4 mS cm^{-1} and hence a need for the amendment of soils samples by mixing it with the poultry manure to reduce potential threat of salinity exacerbated by poultry manure. This increase in EC due to chicken manure addition is consistent to the study by Agdebe *et al.* (2008), whereby there was an increase in exchangeable bases, when poultry manure was added to the soil. While the EC increases with manure, there is however variation in terms of spinach yields associated with salinity. To evaluate the effects of salinity, we plotted the both the fresh and dry biomass with corresponding EC values.

The results show an initial increase in spinach yield with increasing the EC (upto 2 dS m^{-1}) and subsequently dropped with more adverse effects noticed at 4 dS $m^{-1}$for the case of Calcisol (Fig. 5). However, for the other soil types, the spinach yield generally decreased significantly ($p>0.05$) with increasing EC with more adverse impacts at 8 dS m^{-1} (Fig. 5). This could be attributed to the amount of the salts due to addition of the chicken manure. The carrot was the most affected since its growth took place only in the untreated soils, because of sensitive of carrot (Blaylock, 1994; FAO/RNE, 2003).

CONCLUSION

Yield of both crops was significantly decreased with the application rate in Vertic Luvisols than in Luvic Calcisol. At about application rate of 40%, there was virtually no growth suggesting the adverse effects of poultry manure above this rate. The carrot crop was the most affected because of its sensitive to salts, with virtually no growth observed even in the addition of 5% manure. Irrespective of the treatments Arenosols in most cases yielded best results than other soil types and spinach crop performed better than carrots probably due to the high sensitivity of carrot to salinity.

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