Journal of Agriculture and Sustainability

ISSN 2201-4357

Volume 7, Number 2, 2015, 128-142

Nutrient Status and Ameliorating Effects of Poultry Droppings on Soil pH and Sustainable Production of Garden Egg

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Abstract. Sustainable production of crops on tropical soils requires soil amendment to remediate soil acidity status and raise fertility level. Industrial lime and inorganic fertilizers are either not available or too expensive to buy. This study was carried out with the objective of investigating the effects of poultry droppings on soil acidity amelioration and increased fertility for sustained production of garden egg (*Solanum aethiopicum* L.).The field trials were conducted at the Teaching and Research Farms of the University of Agriculture, Makurdi, and the Faculty of Agriculture, Cross River University of Technology, Obubra in 2009 and 2010. Two varieties of African garden egg (Gilo and Kumba) and three rates of poultry droppings (5, 10 and 15 t ha^{-1}) were in factorial combinations. The experiment was laid out in a Randomized Complete Block Design with three replications. The results obtained showed that all rates of the manure reduced the soil pH within 30 days after incorporation in both years and locations. At 60 days after application, and up to 140 days after incorporation, all manure rates increased the soil pH in both locations and years. The highest increase occurred with 15 t ha^{-1} poultry droppings at 140 days after incorporation. With no manure application, there was a steady decrease in pH up to the harvest time. All manure rates significantly (P<0.05) increased the yield of the garden egg varieties over when no manure was used. Poultry droppings at 15 t ha^{-1} produced the highest fruit yield in both years and locations. The crop yields were significantly (p<0.05) higher in Makurdi than Obubra in both years. Yield for 2010 was significantly higher than 2009 in both locations. Poultry dropping at the rate of 15 t ha^{-1} may be used to remediate soil pH and improve fertility for sustainable production of garden egg in the Guinea savanna or the Rainforest agro-ecologies.

Key words; Garden egg, poultry droppings, soil acidity remediation

1. Introduction

African garden egg (*Solanum aethiopicum* L.) is a fruit vegetable in the Family Solanaceae. It is one of the most commonly consumed fruit vegetables in tropical Africa, in quantity and value, probably the third after tomato and onion and before okra (PROTA, 2010). In the Middle Belt and South Eastern Nigeria, the immature fruits are eaten mainly in the fresh state. The leaves, especially of the bitter variety called 'angla', are a delicacy in soups and salads.

Reliable statistics on production, utilization and trade of African eggplant in Nigeria and elsewhere are limited. Production is mainly from small scale holdings that are estimated to account for over 80% of the total production (PROTA, 2010). However, current production cannot meet up with increasing demands for the vegetable in cities and for exportation.

Declining soil fertility and high acidity have been identified as the fundamental cause of declining crop yields in many parts of Africa (Sanchez *et al.*, 1997). Soil acidity is a major constraint in soil fertility maintenance particularly in the humid tropics. As the soil pH declines, the supply of most plant nutrients decreases while aluminum and a few micronutrients become more soluble and toxic to plants. These problems, according to Harter (2007), are particularly acute in humid tropical regions that have been highly weathered. Sanchez and Logan (1992) had earlier observed that one-third of the tropics or 1.7 billion hectares of tropical land is acidic enough for soluble aluminum to be too toxic for most crop plants.

One of the problems of soil acidity includes the fixation of phosphorus by the oxides of Al and Fe to form complexes that are insoluble in water, making it unavailable to the plants. Aluminum, hydrogen and manganese cause root injuries, which affect the uptake of some important mineral nutrients from the soil and this consequently affect crop growth and yield (Lee *et al.*, 2007). Onyekwere *et al.* (2004) also reported that soil acidity has negative effects on bacteria population and activities, which could lead to reduced nitrogen transformation in the soil.

Liming materials and fertilizers are either not available or too expensive for subsistence farmers in the tropics. The use of liming materials from agricultural and domestic wastes has been found to improve the availability of nutrients in the soil, increase crop yields and activities of soil micro organisms due to amelioration of soil pH (Booth and Wickens, 1998; Ojeniyi *et al.*, 1999; Ano and Agwu, 2005; Kekong *et al.*, 2010; Undie, *et al.*, 2013). Our objective was to evaluate the efficacy of poultry droppings for soil pH regulation, soil fertility maintenance and garden egg yield in two contrasting agro-ecologies of Nigeria.

2. Materials and Methods

The study was carried out at the Teaching and Research Farms of the University of Agriculture, Makurdi (7^0 45' N, 8^0 35' E) and Faculty of Agriculture, Cross River University of Technology, Obubra (6^0 06' N, 8^0 18' E). Makurdi is located within the sub humid Guinea Savanna agro ecology of Nigeria while Obubra is in the Rainforest zone. Makurdi has an annual rainfall of 1000 mm – 1250 mm while its mean annual temperature is 25.4^0C. Obubra is characterized by a mean annual rainfall of 2250 mm – 2500 mm, with an annual temperature range between 25^0C and 27^0C.

Treatments consisted of factorial combinations of three rates of poultry droppings of 5, 10 and 15 t ha^{-1}(designated as P_5, P_{10} and P_{15}, respectively) with two varieties of garden egg: Gilo (V_1) and Kumba (V_2). These gave a total of six treatment combinations of P_5V_1, P_5V_2, $P_{10}V_1$, $P_{10}V_2$, $P_{15}V_1$, and $P_{15}V_2$. The treatments were laid out in a Randomized Complete Block Design and replicated three times.

At the commencement of the experiment, a composite soil sample from ten random points was collected using a soil Auger at the 0-30cm depth for both years and locations.

Post manuring and planting soil samples were collected for each treatment and replicated three times. Samples for each treatment were bulked for the three replications at 30, 60 and 90 days after application (DAP) and at harvest (140 DAP). These samples were air-dried, sieved through a 2 mm mesh and packed in paper bags for laboratory analysis.

A net plot of inner ridges in each plot (treatment) was used with four tagged plants for fruit count per plant per harvest and fruit weight. The mean cumulative number of fruits per plant for the number of harvests was taken. The cumulative yield per net plot from first harvest to the last harvest for each plot was calculated as yield in tonnes per hectare.

The soil samples collected were subjected to routine analyses at the Soil Science Laboratory of the Federal University of Technology, Minna, Nigeria, and the Federal University of Agriculture, Makurdi, Nigeria.

Particle size distribution (PSD) was determined by the Bouyoucos (Hydrometer) method as described by Udo *et al.* (2009). Soil pH was determined in both water and KCl in a ratio of 1:1 soil: water and 1:2.5 soil: KCl (Udo *et al.,* 2009).

The Walkley – Black wet method as outlined by Page *et al*. (1982) was used to determine organic matter. Total Nitrogen was determined by the Macro Kjeldahl method as described by Udo *et al.* (2009), while available phosphorus was determined by Bray-I method as outlined by Page *et al.* (1982). Exchangeable cations were determined by the ammonium acetate extraction method as described by Udo *et al*. (2009).

Analysis of variance (ANOVA) for RCBD was performed on the garden egg yield and yield components using the computer software Genstat, (Genstat, 2005). F-LSD was calculated at the probability levels of $P < 0.05$ and $P < 0.01$ to separate the means. T-test was used to determine the location and year effect on crop yield (Gomez and Gomez, 1984).

3. Results

Results of initial soil properties before application of treatments in the two locations and manure analyses are presented in Tables 1 and 2. The soils at both locations were sandy-loam, low in organic matter (OM), N, P, exchangeable cation and CEC. The CEC and OM were, however, relatively higher in Makurdi than Obubra. The soils were slightly acidic in Makurdi and moderately acidic in Obubra, with a higher exchangeable acidity in Obubra than Makurdi.

Changes in soil pH presented in Tables 3 and 4 show that application of poultry droppings increased the pH of the soils at all the manure rates especially at the higher rates from 60 days after incorporation. At 30 days after application, there was a slight decrease in the soil pH in all treatments, including the control. The control showed a steady decline in soil pH from 30 days and up to 140 days after incorporation of the manure in the two locations and in the two years. From 60 days after incorporation of poultry droppings, there was an increase in the soil pH up to 90 days. There was no further increase beyond 90 days after the manure application. The highest increase in soil pH was observed in poultry droppings at 15 t ha^{-1}. The least increase was observed in the manure rate of 5 t ha $^{-1}$ in both the locations and in both the years.

Results showing plant dry matter and number of fruits per plant as affected by the different manure rates are presented in Tables 5. In both the years, application of poultry droppings at 15 t ha^{-1} produced the highest amount of plant dry matter in each location. The lowest yields were obtained when no manure was used. There was no significant difference in dry matter yield between Gilo and Kumba varieties of the crop in Makurdi or in Obubra within each year. The number of fruits per plant followed the same trend as that of plant dry matter in both the years and locations.

At each treatment level, there was no significant difference in fruit yield between the two varieties of garden egg in 2009 or 2010 (Table 6). Across varieties, the highest amount of fruit yield was obtained at 10 t ha^{-1} of poultry droppings, both in 2009 and

2010. All the yield differences were significant. The lowest yield in each variety was obtained when no manure was used.

Results of year and location effects of poultry droppings on the yield of garden egg are presented in Tables 7. Application of poultry droppings produced fruit yields that were significantly higher ($p < 0.05$) in 2010 than in 2009, at all treatment levels and locations. Within the same year, fruit yields were significantly higher in Makurdi than Obubra at all the treatment levels.

4. Discussion

The consistent increases in soil pH with increasing rates of poultry droppings as observed in this study agreed with the earlier findings by Ojeniyi *et al.* (1999), Ano and Agwu (2005) and Kekong *et al.* (2010).

The mechanism responsible for this increase in soil pH was probably due to ion exchange reactions which occur when terminal OH^- of Al^{3+} and Fe^{2+} hydroxyl oxides are replaced by organic anions which are products of decomposition of organic manures as suggested by Bell and Besho (1993). The ability of organic manure to increase soil pH can be attributed to the enrichment of the soil through mineralization of cations particularly Ca. Natschner and Schwartzman (1991) reported that such basic cations are released upon microbial decarboxylation. Narambuye and Haynes (2006) reported that the short-term effects of manure in reducing potentially toxic Al^{3+} solution are attributed to both increase in pH and a complexing effects by soluble organic matter. The decrease in soil pH within the first 30 days was similar to the observations of Haynes and Mokolobate (2001). They opined that this initial decrease in soil pH with organic manure application was due to the buffering reserves of acidity in soils and nitrification of accumulated N. Similarly, Naramibuye and Haynes (2006) noted that in the early stages of degradation, microbial processes of decarboxylation of organic acid anions during manure decomposition are unlikely to contribute to elevated pH.

The significant increase in yield and yield components of garden egg varieties is a manifestation of the positive effect of organic manures on soil properties that transformed into soil fertility and a confirmation of the high mineralizable nutrient composition of poultry manure. This high mineralizable composition of organic manures have earlier been reported by Warman (1986), Bahmann and James (1997) and Duncan (2005). The yield response of the crop varieties due to these organic manure sources agreed with the assertions by Isitekhale and Osemota (2010) that organic manures are important short-term suppliers of nutrients as well as for long-term maintenance of soil organic matter. This yield response showed that the higher the pH above 5 in the soil, the higher the yield of garden egg. Ojeniyi *et al.* (1999) have earlier identified soil pH as one of the most important indicators of soil fertility in the tropics. Sanchez and Logan (1992) who stated that the level of pH, especially in tropical soils, is an essential determinant of its fertility corroborated the yield response of garden egg to increased pH levels above 5 and up to 6.7. The yield increase of Gilo garden egg due to poultry dropping was also reported by Kekong *et al.* (2010).

The higher yield of Gilo variety over Kumba may be attributed to the genotypic characteristics of the crop. Sanginga et al. (2000) have reported this yield differences among crop varieties. They observed that some crop genotypes tend to have greater need for nutrients and are often more responsive to nutrient input.

The higher yield of garden egg varieties in Makurdi (Southern Guinea Savanna) than Obubra (Rainforest) could be attributed to soil properties and climatic variations. Chude (1998) reported that Cross River State soils in the Rainforest zone have low P and exchangeable cations, which are higher in the Nigerian Savanna and this has been confirmed in our current studies.

5. Conclusion

The manurial and organic matter enrichment potentials of poultry droppings and the positive effects on soil pH as observed in this study were found to be efficient in increasing soil pH and maintaining soil fertility for sustainable garden egg production. Application of poultry droppings increased soil pH level and significantly increased garden egg yield, over the control. Poultry droppings have facilitating effects on soil pH and plant nutrients release for optimum production of garden egg in the Nigerian Guinea Savanna and Rainforest agro-ecological zones.

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Table 1: Pre-cropping soil physical and chemical properties at the experimental sites in 2009 and 2010.

	Makurdi		Obubra	
Soil parameters	2009	2010	2009	2010
Sand (g/kg)	874	888	853	839
Silt (g/kg)	84	79	79	72
Clay (g/kg)	42	43	68	89
Texture class	S/L	S/L	S/L	S/L
pH (water)	6.16	6.20	5.50	5.48
pH (KCL)	5.00	4.80	4.30	4.20
Organic matter (%)	2.80	2.76	1.82	1.94
Total nitrogen (g/kg)	1.0	0.9	0.8	0.8
Available P (M/kg)	5.5	4.6	3.6	3.4
Exch. Ca (cmol kg^{-1})	3.40	3.10	2.50	2.61
Exchange. M (cmol kg^{-1})	0.30	0.28	0.22	0.24
Exchange. M (cmol kg^{-1})	0.92	0.98	1.01	1.08
Exchange Na (cmol kg^{-1})	0.16	0.15	0.17	0.18
Exchange. Acidity	2.30	2.25	2.75	2.85
CEC (cmol kg^{-1})	2.3	2.2	1.7	1.8

S/L = sandy loam

Table 2: Nutrient composition of poultry droppings at Makurdi and Obubra in 2009 and 2010

Manure source	N (%)	P (%)	K (%)	Ca (%)	M (%)	Na (%)	Org. C (%)	C:N
			Makurdi					
Poultry manure	1.80	2.4	3.2	6.2	1.96	0.10	7.9	4.4
			Obubra					
Poultry manure	1.72	2.2	2.55	7.0	1.13	0.11	8.2	4.8

Table 3: Effects of organic manure, variety and days after application on soil pH at Makurdi and Obubra in 2009

	Makurdi			Obubra				
		Days after application of manure						
Treatment	30	60	90	140	30	60	90	140
P_5V_1	6.0	6.22	6.21	6.22	5.25	6.00	6.00	6.01
P_5V_2	6.0	6.23	6.23	6.22	5.26	6.01	6.01	6.01
$P_{10}V_1$	6.0	6.30	6.30	6.32	5.15	6.00	6.09	6.09
$P_{10}V_2$	5.98	6.30	6.11	6.22	5.06	5.95	6.08	6.08
$P_{15}V_1$	5.97	6.24	6.25	6.35	5.04	6.06	6.17	6.17
$P_{15}V_2$	5.99	6.24	6.35	6.35	5.05	6.05	6.16	6.17

P_5 – P_{15} = Poultry droppings rates at 5, 10 and 15 t ha^{-1}; V_1=Gilo, V_2=Kumba

Table 4: Effects of organic manure, variety and days after application on soil pH at Makurdi and Obubra in 2010

	Makurdi			Obubra				
		Days after application of manure						
Treatment	30	60	90	140	30	60	90	140
P_1V_1	5.91	6.30	6.58	6.50	5.29	5.61	5.60	5.61
P_1V_2	6.04	6.30	6.60	6.60	5.30	5.59	5.60	5.61
P_2V_1	6.01	6.41	6.58	6.58	5.25	5.90	6.00	6.00
$P_{52}V_2$	6.00	6.40	6.68	6.60	5.27	5.80	5.95	5.97
P_3V_1	5.98	6.31	6.70	6.71	5.25	6.60	6.10	6.10
P_3V_2	6.04	6.40	6.71	6.70	5.28	6.00	6.11	6.00

P_5 – P_{15} = Poultry droppings rates at 5, 10 and 15 t ha^{-1}; V_1=Gilo, V_2=Kumba

Table 5: Plant dry matter and number of fruits per plant of two varieties of garden egg as affected by rates of application of poultry droppings at Makurdi and Obubra in 2009 and 2010

	Plant dry matter (kg/ha $^{-1}$)				Number of fruits per plant			
	2009		2010		2009		2010	
Treatment	Makurdi	Obubra	Makurdi	Obubra	Makurdi	Obubra	Makurdi	Obubra
Control	58.5	58.3	58.0	55.5	11.2	8.50	26.5	25.0
P_1	126.5	134.7	142.0	131.3	41.33	37.17	49.5	44.83
P_2	186.2	172.3	233.0	182.2	52.83	47.17	70.3	61.50
P_3	200.3	199.8	257.0	246.8	64.50	57.67	84.8	73.33
LSD (P<0.05)	9.16	18.23	18.44	14.10	5.0	3.18	10.90	5.25
V_1	148.9	145.5	175.5	162.1	52.4	44.67	81.8	74.3
V_2	146.7	139.1	179.6	173.6	28.0	24.00	31.9	29.2
LSD(P<0.05)	NS	NS	NS	NS	2.26	1.42	4.88	2.35

NS = not significant; P_5 – P_{15} = poultry droppings rates at 5, 10 and 15 t ha^{-1}; V_1=Gilo, V_2=Kumba

Table 6: Fruit yield of two varieties of garden egg as influenced by rates of application of poultry droppings at Makurdi and Obubra in 2009 and 2010

	Fruit yield (t ha^{-1})			
	2009		2010	
Treatment	Makurdi	Obubra	Makurdi	Obubra
Control	1.18	0.92	3.32	2.97
P_5	4.40	4.03	7.97	6.15
P_{10}	9.18	8.65	11.87	10.13
P_{15}	7.28	6.62	10.02	8.10
LSD (P<0.05)	0.47	0.67	1.31	0.77
V_1	5.89	5.39	8.53	7.66
V_2	4.67	4.65	8.30	6.79
LSD(P<0.05)	0.21	0.31	NS	0.34

NS = not significant; P_5 – P_{15} = Poultry droppings rates at 5, 10 and 15 t ha^{-1}; V_1=Gilo, V_2=Kumba

Table 7: Location and year effects on fruit yield of two varieties of garden egg as affected by rates of application of poultry droppings at Makurdi and Obubra in 2009 and 2010

	Fruit yield ($t\ ha^{-1}$)							
	2009		2010		Makurdi		Obubra	
Treatment	Makurdi	Obubra	Makurdi	Obubra	2009	2010	2009	2010
P_5V_1	4.87	4.37	6.97	6.67	6.97	4.87	6.67	4.37
P_5V_2	3.93	3.70	8.97	5.63	8.97	3.93	5.67	4.37
$P_{10}V_1$	7.73	6.93	10.00	8.60	10.00	7.73	8.60	6.93
$P_{10}V_2$	6.83	6.30	10.03	7.60	10.03	6.83	7.60	6.30
$P_{15}V_1$	9.87	9.17	12.33	10.63	12.33	9.87	10.67	9.17
$P_{15}V_2$	8.50	8.13	11.40	9.60	11.40	8.50	9.60	8.13
$\dot{X}$	5.28	5.05	8.42	7.23	8.42	5.28	7.23	5.04
SE±	0.069		0.177		0.35		0.14	

P_5 – P_{15} = Poultry droppings rates at 5, 10 and 15 $t\ ha^{-1}$; V_1=Gilo, V_2=Kumba