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Effects of Chicken Manure on Soil Properties under Sweetpotato [*Ipomoea batatas* (L.) Lam.] Culture in Swaziland

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Abstract: Small-scale farmers rarely use chicken manure in sweetpotato [*Ipomoea batatas* (L.) Lam.] production in Swaziland. Increasing fertilizer prices have made farmers to turn to other sources of plant nutrients for their crops. It not clear what effects chicken manure might have on soil properties and yield of sweetpotato. The objective of this investigation was to evaluate the effects of different levels of chicken manure on soil temperatures, weed infestation, soil moisture content and yield of sweetpotato. Five treatments [(1), no chicken manure; (2), 20 t/ha chicken manure; (3), 40 t/ha chicken manure; (4), 60 t/ha chicken manure; and (5), 350 kg/ha of compound fertilizer] were evaluated in a randomized complete block design, replicated four times. Results showed that temperature at the soil surface was significantly ($p < 0.05$) higher than at lower depths and was negatively but not significantly correlated to some parameters: leaf area ($r = - 0.009$; $n = 20$); leaf area index ($r = - 0.002$; $n = 20$); specific leaf area ($r = - 0.561$; $n = 20$); net assimilation rate ($r = - 0.128$; $n = 20$); and crop growth rate ($r = - 0.173$; $n = 20$). Weed density was negatively but not significantly correlated to the tuber yield ($r = - 0.235$; $R^2 = 0.055$; $n = 20$) and marketable tuber yield ($r = - 0.317$; $R^2 = 0.100$; $n = 20$) at 8 weeks after planting (WAP). Soil moisture content was negatively but not significantly correlated to some parameters: soil temperature at surface ($r = - 0.287$; $n = 20$); soil temperature at 5-cm depth ($r = - 0.013$; $n = 20$); and soil temperature at 10-cm depth ($r = - 0.020$; $n = 20$). Sweetpotato yields declined with increased levels of chicken manure: 20 t/ha chicken manure yielded (20.6 t/ha); 40 t/ha chicken manure yielded (19.3 t/ha); and 60 t/ha chicken manure yielded (13.3 t/ha). It is recommended that high levels of chicken manure be not used for sweetpotato production; further research on beneficial levels of chicken manure is recommended.

Key words: Chicken manure · Organic farming · Soil moisture content · Soil temperature · Sweetpotato · Weed infestation · Yield

INTRODUCTION

Organic farming is a productive system, which largely avoids the use of synthetic fertilizers, pesticides, growth regulators, preservatives and livestock additives. Organic agricultural practices rely mostly on crop residues, animal manures, crop rotation and green leaf manure, off-farm organic wastes and biofertilizers to supply plant nutrients and adopt biological control methods to control pests, diseases and weeds [1].

Animal manures (such as farmyard manure and chicken manure) are excellent fertilizers for crops and forages. Manure contains nitrogen, phosphate, potash and micronutrients that are essential for plant growth. Also, applying manure to farmland can improve soil tilth, increase water-holding capacity, reduce water and wind erosion, improve aeration and promote beneficial organisms [2].

National food security is a critical issue in Swaziland. More than a quarter of the population currently lives on World Food Aid due to poverty, drought and the effects of HIV (Human Immuno-deficiency Virus) and AIDS (Acquired Immune Deficiency Syndrome) on traditional subsistence agriculture. Around 69% of Swaziland's one million people live below the poverty line, subsisting on $0.60 a day [3]. Poverty is driven by the persistent drought that has caused famine in many rural communities in Swaziland. In addition, there is the loss of income earnings through retrenchments and general unemployment has increased, thus contributing

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to the lack of access to productive resources by poor families [3].

Sweetpotato [*Ipomoea batatas* (L.) Lam.] is a warm-season, viny, storage root that requires a long frost-free growing season to mature. Sweetpotato is native to Central and South America [4]. Sweetpotato is a crop, which reliably provides food on marginal and degraded soils with little labour and few or no inputs from outside the farm. The crop is efficient in the production of carbohydrates, proteins, vitamins and cash income per unit of land and time. The exploitation of this potential has been limited in Eastern and Southern Africa by the restricted ways in which the crop is utilized. Compared to other tropical food and cash crops, the sweetpotato has received relatively less research attention [5].

The ever-escalating farm input prices coupled with the ravaging drought have proven to be major challenges for small-scale farmers in Swaziland. Inorganic fertilizers are too costly for rural, resource-poor households with their limited income; it is difficult for these households to obtain loans from any banks to purchase farming inputs such as fertilizers. Such farmers must, therefore, exploit locally available resources to fertilize their crops and farmlands.

Among the recent developments in sweetpotato farming in Swaziland has been that the Taiwan International Cooperation and Development Fund operating in Swaziland established a project called "Small Farmer Corn and Sweetpotato Project," which assisted smallholders to expand corn (*Zea mays* L.) and sweetpotato production on public land. In 2004, the Mission continued its assistance in four Provinces throughout Swaziland. Fifty hectares of corn were cultivated in each Province. Sweetpotato farming was expanded in every Province and other crops including cabbage, tomato, beets and carrot, were grown [6]. These were attempts to make farmers produce staple foods and raise self-sufficiency and boost farmer incomes.

This experiment was a strategy of looking for natural and readily available sources of nutrients for sweetpotato without the use of inorganic fertilizers. The specific objective of this study was to determine the effects of different levels of chicken manure on ecological characteristics such as soil temperature, weed infestation, soil moisture content and yield of sweetpotato.

MATERIALS AND METHODS

Experiment Site: This Swaziland field study was conducted in the Middleveld agro-ecological zone at the Malkerns Research Station. The research station is located at 26.34°S, 31.10°E, and is 750 m above sea level. The mean annual rainfall range is 800-1,000 mm and the mean annual temperature is 18°C [7]. The dark loam to sandy loam soil on the Malkerns Research Station is classified as an Oxisol of the Malkerns soil series [8].

Treatments: Sweetpotato was grown at an intra-row spacing of 30 cm and inter-row spacing of 100 cm. The five treatments of the investigation were: (1), Control (no chicken manure applied); (2), 20 t/ha of chicken manure; (3), 40 t/ha of chicken manure; (4), 60 t/ha of chicken manure; and (5), a compound fertilizer.

Experimental Design, Replication and Plot Size: The experimental design was a randomized complete block design and each treatment was replicated four times. Thus, there were 20 plots, each with seven ridges. Each plot was 5.4 m long and 6.0 m wide.

Land Preparation: The land was plowed and disked using a moldboard plow and disc harrow, respectively. Ridges were made using a tractor-mounted ridger at an inter-row spacing of 1.0 m. The ridges were then molded manually using hoes, to obtain the desired ridge shape.

Soil Sampling, Lime and Fertilizer Application: Soil sampling was done to a 15-cm depth and one composite sample from all plots was used for chemical analysis. Based on the chemical analysis, dolomitic lime ($CaMgCO_3$) was applied at 1.17 tonnes/ha. It had earlier been recommended that in sweetpotato production in Swaziland, if soil pH is below 5.3, agricultural lime should be applied [9]. Lime was applied before planting, by broadcasting on the ridges and incorporated into the ridges using hand hoes.

Chicken manure was obtained from a nearby commercial poultry house and kept in the open for four weeks, to "age" or allow for decomposition. The aged manure was applied immediately after planting following the different levels specified in the treatments. A compound fertilizer [N-P-K, 2:3:2 (38)] containing 0.5% zinc was applied at 350 kg/ha, followed by side dressing (120 kg/ha) at 6 weeks after planting (WAP), using 10 parts of urea (45% N) and 50 parts of muriate of potash, KCl (60% K) at a rate of 120 kg/ha. The method of application was the banding and incorporation method.

Planting: Planting was done on 16 December 2009, using the 'Kenya' variety of sweetpotato. Vines were obtained from plots at Malkerns Research Station. Vine preparation was done one day before planting. All open leaves were detached from mature vines, each of which was cut to 30 cm in length. The removal of leaves was done to reduce transpiration and ensure good vine establishment. The vines were planted at an intra-row spacing of 30 cm and inter-row spacing of 100 cm; one vine was planted per planting station, at an angle, with about two-thirds of the cutting below the soil.

Irrigation, Gap Filling and Weeding: Irrigation was done using overhead sprinklers. During the first WAP, irrigation was done after every two days because rains were not yet regular. After the establishment of the vines, irrigation was done once every week depending on the weather conditions. On each occasion, the soil was irrigated to field capacity. Gap filling was done within two WAP to ensure the desired plant population. Following the weed score evaluation, all plots were manually weeded at 4 and 8 WAP to reduce weed competition. During weeding, the ridges were molded using hand hoes.

Data Collection: Soil temperatures were measured between 1400 hours and 1600 hours during a sunny day, without rain and was measured at 10 cm away from the base of the plants at the surface, 5 cm and 10-cm depth. Three measurements per station were made using Fisherbrand bi-metal dial soil thermometers [10]. A 90-cm square quadrat was used to assess weed infestation at 4 and 8 WAP. Weed infestation was estimated visually using a weed score scale of 1 to 6 [10-12]. On this scale, the following descriptions were ascribed to the weed scores: (1), zero weeds on soil within the quadrat; (2), sparse weed coverage; (3), intermediate weed coverage; (4), general weed coverage; (5), severe weed coverage; and (6), very severe weed coverage. Weeds within the quadrat were then identified using weed manuals and textbooks [13] and classified; three determinations per plot were done. The relative abundance of the different weed species was assessed on the basis of the proportion or percentage of the quadrat that was occupied by each weed species.

At harvest (20 WAP), soil was sampled from each experimental row per plot for determination of soil moisture content. The soil was weighed and oven-dried at 105°C for 52 hours. After oven-drying, the samples were re-weighed and the following formula was used to calculate the soil moisture content on dry mass basis [14]:

$$\text{Moisture content (dry mass basis)} = \frac{\text{[Mass of wet soil - mass of dry soil] (g)}}{\text{Mass of dry soil (g).}} \times 100$$

Harvesting was done using garden forks. Only the experimental row, which was kept for yield was harvested per plot and discard stands on each ridge end were not harvested. Marketable tubers were whole tubers that had no wounds and weighed between 100 g and 1.4 kg; non-marketable tubers were tubers that had harvest wounds or outside the mass range for marketable tubers [15]. Soil in each plot was sampled and analyzed for nutrient element concentrations. Meteorological information was collected from Malkerns Research Station.

Data Analysis: Data were analyszd using MSTAT-C statistical program, version 1.3 [16]. The least significant difference test [17] was used for mean separation at 5% level of significance.

RESULTS AND DISCUSSION

Meteorological Information: Figure 1 shows the trends in meteorological information at Malkerns Research Station. A total of 774.0 mm was received during the period of experiment. An average mean minimum temperature and maximum temperature of 17.0°C and 26.6°C was experienced, respectively. Crop growth could be influenced by rainfall amount and distribution during the cropping season. Irrigation must have mitigated water stress on the sweetpotato crop. Rainfall amounts and distribution are known to affect crop growth and yield. [18] noted that supplemental irrigation at a critical time to mitigate water stress and increase yields is an efficient agronomic practice.

Soil Temperature: Table 1 shows the soil temperatures of sweetpotato at 4-20 WAP. There were no significant differences in soil temperatures at surface and 10-cm depth on sweetpotato among the treatments, but there were significant ($p < 0.05$) differences in soil temperatures at 5-cm depth. Temperatures at the soil surface were not significantly higher in plots with no chicken manure and 20 t/ha of chicken manure, with high mean values of 32.4°C and 32.3°C, respectively. Though agronomic data are not shown in this report, the correlation matrix (Table 2) shows various correlations between soil temperatures and various agronomic parameters.

Plant growth and tuber yields were least affected by low soil and water temperatures, as during the period from rice heading to crop maturity [19]. High levels of chicken manure caused an increase in crop canopy that helps to protect the soil against the deleterious effects of exposure to rain and sun, thus conserving soil moisture and maintaining constant soil temperature for growth [20].

Weed Infestation: Tables 3 and 4 show the relative abundance (%) and diversity of weed species in sweetpotato at 4 and 8 WAP, respectively. There were significant ($p < 0.05$) differences on the weed density of sweetpotato among the treatments at 4 and 8 WAP.

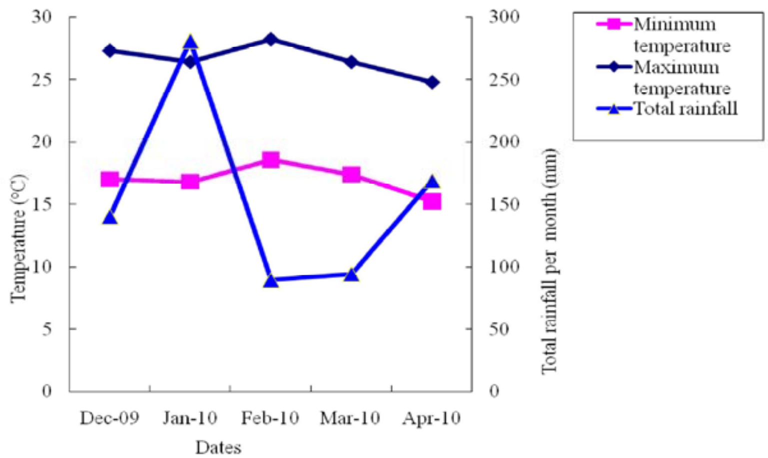

Fig. 1: Rainfall (mm) and temperature (°C) during the experiment, from December 2009 to April 2010

Table 1:Soil temperatures (°C) in sweetpotato at 4-20 weeks after planting.

		Weeks after planting and soil temperature (°C)					
Treatments	Soil depth	4	8	12	16	20	Means
No chicken manure	Surface	39.6a	32.8b	30.4a	30.4a	28.7ab	32.4a
	5-cm	38.2b	34.5b	28.9a	29.2a	28.2a	31.8b
	10-cm	35.6b	30.8b	26.5b	27.4a	25.1a	29.1a
20 t/ha chicken manure	Surface	39.4a	32.1b	30.9a	29.6a	29.7b	32.3a
	5-cm	36.5ab	32.6a	26.8a	28.7a	28.7a	30.7ab
	10-cm	34.5a	30.8b	26.0b	26.2a	26.2a	28.7a
40 t/ha chicken manure	Surface	40.2a	29.1a	29.7a	31.6b	29.0b	31.9a
	5-cm	34.3a	30.3a	26.3a	29.3a	27.8a	29.6a
	10-cm	34.1a	29.6a	24.3a	27.4a	26.2a	28.3a
60 t/ha chicken manure	Surface	35.6a	31.9b	29.7a	32.0c	29.5b	31.7a
	5-cm	34.7a	31.4a	27.6a	29.1a	27.9a	30.1ab
	10-cm	32.7a	29.1a	26.3b	26.3a	25.6a	28.0a
350 kg/ha compound fertilizer	Surface	40.3a	32.3b	30.3a	30.8b	27.5a	32.2a
	5-cm	36.9a	31.1a	28.9a	29.0a	27.8a	30.7ab
	10-cm	34.6a	29.9a	26.8b	25.3a	25.5a	28.4a
Means	Surface	39.0	31.6	30.2	30.9	28.9	32.1
	5-cm	36.7	32.0	27.7	29.1	28.1	30.7
	10-cm	34.3	30.0	26.0	26.5	25.7	28.5

Numbers in the same column followed by the same letters are not significantly different according to the least significant difference test.

Table 2: Correlation matrix for the parameters measured on sweetpotato at 20 weeks after planting.

Parameters	Vine length	Number of leaves	LA	LAI	SLA	SLM	CGR	NAR	Soil temp. at surface	Soil temp. at 5-cm tuber depth	Non-marketable yield	Soil moisture content	Total tuber yield	Marketable tuber yield	Non-Marketable tuber Yield
Number of leaves	0.524*														
Leaf area (LA)	0.108Ns	0.567*													
Leaf area index (LAI)	0.106 Ns	0.557*	0.999*												
Specific leaf area (SLA)	- 0.057Ns	0.138 Ns	0.357Ns	0.354Ns											
Specific leaf mass (SLM)	0.049 Ns	- 0.108Ns	- 0.308Ns	- 0.305Ns	- 0.995Ns										
Crop growth rate (CGR)	- 0.017 Ns	0.176 Ns	0.062Ns	0.055Ns	- 0.064Ns	0.093Ns									
Net assimilation rate (NAR)	- 0.015 Ns	0.171 Ns	0.025Ns	0.017Ns	- 0.097Ns	0.120Ns	0.990Ns								
Soil temperature at surface	0.114 Ns	0.164 Ns	- 0.009Ns	- 0.002Ns	- 0.561Ns	0.554*	- 0.173Ns	-0.128Ns							
Soil temperature at 5-cm depth	0.065 Ns	- 0.310Ns	- 0.327Ns	- 0.316Ns	- 0.304Ns	0.328Ns	- 0.150Ns	- 0.149Ns	0.192Ns						
Soil temperature at 10-cm depth	0.156 Ns	0.282Ns	0.087Ns	0.105Ns	- 0.110Ns	0.154Ns	0.126 Ns	0.135Ns	0.194Ns	0.253Ns					
Soil moisture content	0.064 Ns	- 0.131Ns	0.048Ns	0.044Ns	0.196Ns	- 0.195Ns	- 0.319Ns	- 0.313Ns	- 0.287Ns	- 0.013Ns	- 0.020Ns				
Total tuber yield	- 0.244 Ns	- 0.238Ns	0.094 Ns	0.097Ns	0.240Ns	- 0.221Ns	- 0.097Ns	- 0.102Ns	- 0.377Ns	0.020Ns	0.076Ns	0.300Ns			
Marketable tuber yield	- 0.177 Ns	- 0.150Ns	0.042Ns	0.125Ns	- 0.110Ns	- 0.094Ns	- 0.095Ns	-0.365Ns	-0.013Ns	0.097Ns	0.097Ns	0.257Ns	0.962*		
Non-marketable tuber yield	- 0.355Ns	- 0.412Ns	0.123Ns	0.128Ns	0.483*	- 0.472Ns	- 0.249Ns	- 0.271Ns	- 0.321Ns	0.031Ns	- 0.132Ns	0.259Ns	0.621*	0.447*	
Income from marketable tubers	- 0.177Ns	- 0.150Ns	0.042Ns	0.125Ns	- 0.110Ns	- 0.094Ns	- 0.095Ns	- 0.365Ns	- 0.013Ns	0.097Ns	0.097Ns	0.257Ns	0.962*	1.00*	0.477*

* Significant at $p < 0.05$; and Ns, not significant

Table 3: Effects of different levels of chicken manure on the relative abundance (%) and diversity of weed species in sweetpotato at 4 weeks after planting

Weed species	Common name of weeds	No chicken manure	Treatments and relative abundance (%)[1] 20 t/ha chicken manure	40 t/ha chicken manure	60 t/ha chicken manure	350 kg/ha fertilizer
Acanthospermum glabratum (DC.) Wild.	Five-seed prostrate starbur	1.5	0.2	1.9	0.0	2.8
Acanthospermum hispidum DC.	Upright starbur	0.4	2.1	0.6	0.3	0.0
Ageratum conyzoides L.	Invading Ageratum	3.1	1.0	0.6	0.0	0.4
Amaranthus hybridus L.	Common pigweed	0.0	0.0	0.0	0.2	0.0
Amaranthus thunbergii Moq.	Red pigweed	1.7	0.0	0.0	0.0	0.0
Bidens pilosa L.	Common blackjack	10.0	12.1	7.9	9.2	9.2
Cleome monophylla L.	Spindlepod	0.4	1.3	1.7	1.5	2.8
Commelina benghalensis L.	Benghal wandering Jew	6.0	2.8	7.4	6.1	2.0
Convolvulus arvensis L.	Bindweed	4.0	6.0	4.6	8.6	2.4
Cynodon dactylon (L.) Pers.	Star grass	26.9	28.3	37.0	31.9	28.8
Cyperus esculentus L.	Yellow nutsedge	7.9	13.6	15.7	13.0	12.1
Datura ferox L.	Thorn apple	0.0	0.0	0.0	0.8	0.0
Eleusine coracana L.	Goose grass	2.9	1.7	0.8	1.3	2.6
Oxalis latifolia H. B. K.	Red garden sorrel	1.3	0.8	0.0	0.0	5.4
Panicum maximum L.	Common buffalo grass	0.8	0.4	2.3	0.6	0.7
Richardia brasiliensis	Tropical Richardia	17.4	15.0	11.4	15.1	17.3
Tagetes minuta L.	Khakhi weed	15.4	14.7	8.0	11.4	13.5
Weed score	NA	3.8b	2.7a	3.3a	3.0ab	3.7b

[1]Because of rounding up of percentages, the relative abundance may not equal 100%.
Numbers in the same row followed by the same letters are not significantly different according to the least significant difference test.
NA, Not applicable

Table 4: Effects of different levels of chicken manure on the relative abundance (%) and diversity of weed species in sweetpotato at 8 weeks after planting

Weed species	Common name of weeds	No manure	Treatments and relative abundance (%)[1] 20 t/ha chicken manure	40 t/ha chicken manure	60 t/ha chicken manure	350 kg/ha fertilizer
Acanthospermum glabratum (DC.) Wild.	Five-seed prostrate starbur	0.6	4.2	5.4	1.7	2.5
Acanthospermum hispidum DC.	Upright starbur	0.0	0.3	0.4	0.0	0.0
Ageratum conyzoides L.	Invading Ageratum	6.0	1.3	4.2	1.4	0.8
Bidens pilosa L.	Common blackjack	8.0	5.2	7.1	4.6	4.2
Cleome monophylla L.	Spindlepod	0.8	0.4	1.7	0.0	3.1
Commelina benghalensis L.	Benghal wandering Jew	11.9	19.6	10.6	10.0	13.5
Convolvulus arvensis	Bindweed	9.5	8.4	6.4	6.2	2.5
Cynodon dactylon (L.) Pers.	Star grass	45.7	38.8	45.8	61.2	55.6
Cyperus esculentus L.	Yellow nutsedge	5.2	5.3	2.7	0.8	4.2
Datura ferox L.	Thorn apple	0.0	0.0	1.7	1.7	0.0
Eleusine coracana	Goose grass	2.5	0.8	0.8	1.7	0.4
Leucas martinicensis	Bobbin weed	0.2	0.0	0.0	0.0	0.0
Oxalis latifolia H.B.K.	Red garden sorrel	2.5	0.0	1.7	0.0	4.2
Panicum maximum	Common buffalo grass	0.8	1.9	0.0	0.8	0.0
Richardia brasiliensis	Tropical Richardia	3.9	10.4	4.6	4.5	6.9
Sporoborus spp.	Couch grass	0.0	0.8	0.0	0.0	0.0
Tagetes minuta L.	Khakhiweed	2.5	2.7	7.0	5.5	2.2
Weed score	NA	2.2ab	2.5b	2.2ab	1.6a	2.3ab

[1]Because of rounding up of percentages, the relative abundance may not equal 100%.
Numbers in the same row followed by the same letters are not significantly different according to the least significant difference test.
NA, Not applicable

There were lower weed densities (weed score, 1.6-2.5 out of 6.0) later in the season (8 WAP) than at 4 WAP (weed score, 2.7-3.8 out of 6.0).

The dominant weed species at 4 WAP were *Cynodon dactylon* (26.9-37.0%), *Richardia brasiliensis* (11.4-17.4%), *Cyperus esculentus* (7.9-15.7%), *Bidens pilosa* (7.9-12.1%) and *Commelina benghalensis* (2.0-7.4%). The dominant weed species at 8 WAP were *Cynodon dactylon* (38.8-61.2%), *Commelina benghalensis* (10.0-19.6%),

Table 5: Soil moisture content (%) of sweetpotato plots at 20 weeks after planting.

Treatments	Soil moisture content (%)
No chicken manure	20.1a
20 t/ha chicken manure	20.2a
40 t/ha chicken manure	20.2a
60 t/ha chicken manure	19.8a
350 kg/ha fertilizer	20.3a
Means	20.1

Numbers in the same column letters followed by the same letters are not significantly different according to the least significant difference.

Table 6: Concentrations of nutrient elements in chicken manure used for growing sweetpotato in Swaziland

Parameter	Total kg/ha
Moisture	186.6
Solids	2053.4
Total nitrogen	37.3
Phosphorus	74.3 (as P_2O_5)
Potassium	64.5 (as K_2O)
Sulfur	9.0
Magnesium	15.8
Calcium	148.8
Sodium	8.6
Aluminum	9.1
Copper	0.2
Iron	9.7
Manganese	1.3
Zinc	1.6

Cyperus esculentus (7.9-15.7%) and *Richardia brasiliensis* (3.9-10.4%). Weed density at 8 WAP was negatively but not significantly correlated to the total tuber yield ($r = -0.235$; $R^2 = 0.055$; $n = 20$) and marketable tuber yield ($r = -0.317$; $R^2 = 0.100$; $n = 20$). The resultant coefficients of determination showed that 5.5% in the variation in total tuber yield and 10.0% in the variation in marketable tuber yield could be associated with the weed density.

That weed density and relative abundance decreased as the cropping season progressed, indicating the shading and smothering influences of the sweetpotato on weeds later in the cropping season, was consistent with an earlier report [21, 22] reported that in corn, higher weed densities observed in the more weedy plots could contribute to reduced crop yields.

Soil Moisture Content: Table 5 shows the soil moisture content at harvest. There were no significant ($p > 0.05$) differences in the soil moisture content (19.8-20.2%) among the treatments. However, plots fertilized with 350 kg/ha fertilizer showed a not significantly higher soil moisture content/plot (20.3%) than other plots. Plots that received 60 t/ha chicken manure had the lowest soil moisture content (19.8%). Soil moisture content was positively but not significantly correlated to some parameters: vine length ($r = 0.064$; $n = 20$); leaf area ($r = 0.048$; $n = 20$); leaf area index ($r = 0.044$; $n = 20$); specific leaf area ($r = 0.196$; $n = 20$) and total tuber yield ($r = 0.300$; $n = 20$). [19] observed that irrigation is used on full season agronomic crops to provide a dependable yield every year.

Soil Chemical Properties: Table 6 shows the nutrient elements found in the chicken manure. Compared to Table 5, there was a higher amount of moisture (19.8-20.2%) in the chicken manure at harvest, than at the start of the experiment (8.3%), indicating that soils with chicken manure absorbed and retained moisture for use by the sweetpotato crop. Table 7 shows the concentrations of soil nutrient elements at harvest. There were no significant differences among all the nutrient levels. Comparing the soil nutrient concentrations at the start and end of the experiment, it was evident that the

Table 7: Chemical analysis for soil nutrient elements at harvest

			Nutrient elements (cmol/kg)					Percent base saturation (%)					Nutrient elements (cmolc/kg)					
Treatments	Organic matter (%)	Available P`	K	Mg	Ca	Soil pH	CEC (cmol/kg)	K	Mg	Ca	H	S`	Zn	Mn	Cu	B	Nitrate N	Total N (%)
No chicken manure	4.0	16.3	40.0	153.8	375.0	5.5	5.4	2.0	23.6	34.7	39.9	15.5	2.9	10.0	1.2	0.3	2.0	0.13
20 t/ha chicken manure	4.2	34.0	49.8	167.5	487.5	5.6	6.1	2.1	23.4	40.4	34.2	15.8	4.3	12.3	1.2	0.3	1.3	0.15
40 t/ha chicken manure	4.1	59.0	59.8	165.0	550.0	5.6	6.4	2.4	21.5	43.0	33.1	17.5	6.2	11.8	1.3	0.3	1.8	0.15
60 t/ha chicken manure	4.2	81.8	77.3	191.3	612.5	5.7	6.7	3.0	23.8	44.8	28.4	17.0	7.5	13.3	1.3	0.3	2.3	0.17
350 kg/ha fertilizer	4.2	37.0	55.5	122.5	437.5	5.2	6.4	2.3	17.4	34.5	45.9	18.3	3.2	8.0	1.6	0.2	1.5	0.14
Means	4.1	45.6	56.5	160.0	492.5	5.5	6.2	2.4	21.9	39.5	36.3	16.8	4.8	11.1	1.3	0.3	1.8	0.15
[1]LSD $_{(p<0.05)}$	0.51	46.58	28.05	51.21	240.64	0.42	1.82	1.04	5.85	10.50	14.90	4.06	3.30	6.84	0.73	0.10	0.78	0.04
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns	Ns
Original soil data	3.1	4.4	44.4	39.3	1258.5	4.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

[1]Least significance difference;
ND, no data available from analysis of original soil;
Significant at $p < 0.05$; and
Ns, not significant

Table 8: Correlation matrix for soil nutrient elements and sweetpotato yield under chicken manure fertilization

Parame-ters	Organic matter	P	K	Ca	Mg	Total N	NO_3-N	Soil pH	CEC	Zn
P	0.200Ns									
K	0.144Ns	0.768*								
Ca	0.402Ns	0.701*	0.481*							
Mg	0.336Ns	0.481*	0.094Ns	0.776*						
Total N	0.333Ns	0.369Ns	0.331Ns	0.331Ns	0.272Ns					
NO_3-N	- 0.067Ns	0.429Ns	0.557*	0.420Ns	0.325Ns	0.046Ns				
Soil pH	0.329Ns	0.319Ns	- 0.039Ns	0.679*	0.970*	0.244Ns	0.243Ns			
CEC	0.175Ns	0.591*	0.613*	0.729*	0.222Ns	0.292Ns	0.347Ns	0.066Ns		
Zn	0.237Ns	0.943*	0.679*	0.834*	0.640*	0.416Ns	0.472*	0.513*	0.601*	
Total tuber yield	0.247Ns	-0.232Ns	-0.289Ns	0.101Ns	0.238Ns	- 0.385Ns	- 0.106Ns	0.274Ns	- 0.055Ns	- 0.200Ns

* Significant at $p < 0.005$; and Ns, not significant

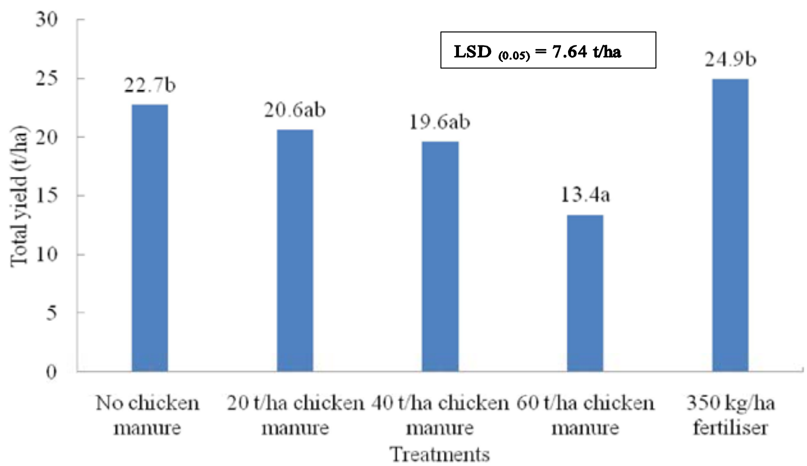

Fig. 2: Total fresh tuber yield/plot (t/ha) in sweetpotato at 20 weeks after planting

experiment improved several soil properties: organic matter from 3.1 to 4.2%; available P from 4.4 to 81.8 cmol/kg; and pH from 4.5 to 5.7. Table 8 is the correlation matrix showing various soil and yield relationships at harvest. Organic matter was positively ($r = 0.247$; $n = 20$) correlated with total tuber yield; the resulting coefficient of determination, R^2, showed that 6.1% increase in organic matter could be associated with improved tuber yield. Soil pH was positively but not significantly correlated with total tuber yield ($r = 0.274$; $n = 20$), showing that 7.5% increase in total tuber yield could be ascribed to increased soil pH.

Sweetpotato grows at a soil pH of 4.5 to 7.5, but 5.8 to 6.2 is optimal for growth and yield of the plant [23]. Dolomitic lime, which supplies both calcium and magnesium, was required to raise the soil pH above from 4.5 in order to improve sweetpotato growth.

Tuber Yields: Figure 2 shows the total fresh tuber yield (t/ha) of sweetpotato (marketable and non-marketable tubers) at 20 WAP. There were significant ($p < 0.05$) differences in the total tuber yield among the treatments. The fertilizer treatment yielded significantly ($p < 0.05$) higher (24.9 t/ha) than the highest amount of chicken manure applied (60 kg/ha, leading to tuber yield of 13.4 t/ha). Increased chicken manure levels decreased tuber yields. There were variations in marketable tubers due to wounds and some tubers weighing outside the marketable mass range, as previously reported [15].

[24] reported that nitrogen fertilizer delays tuber formation and promotes shoot growth at the expense of tuber growth. Lower tuber yield on high levels of chicken manure might have been due to the high nitrogen levels in the soil that promoted vegetative growth at the expense of tuber formation. Large amounts of N decrease cambial activity, but increase lignification, favoring the production of non-tuberous roots [20].

CONCLUSION AND RECOMMENDATIONS

Higher levels of chicken manure did not significantly increase sweetpotato tuber yield; compound fertilizer resulted in the highest yield. It is recommended that small-scale farmers should not apply high levels of chicken manure because higher levels of manure would increase vegetative growth at the expense of tuber formation.

Further research should be conducted to ascertain the optimum levels of chicken manure for application to sweetpotato.

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