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Chicken Manure Affects Sweetpotato [*Ipomoea batatas* (L.) Lam.] Nutrient Element Concentrations in Tubers and Leaves in Swaziland

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ABSTRACT: Increasing fertilizer prices have made farmers turn to other sources of plant nutrients for their crops. Farmers are now making increasing use of farmyard manures to increase soil fertility. It is not clear what effects these manures might have on the concentration of nutrient elements in edible parts of the sweetpotato [Ipomoea batatas (L.) Lam.]. The objective of this field experiment was to determine the effects of different levels of chicken manure on nutrient concentrations in sweetpotato tubers and leaves. Five treatments were assessed in a randomized complete block design, replicated four times.

The treatments were: (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. The experiment was monitored for 20 weeks. Results showed that in sweetpotato tubers, there were significant ($p < 0.05$) increases in concentrations of total nitrogen, sulfur, phosphorus, potassium and copper as chicken manure levels increased. In the leaves, significant ($p < 0.05$) differences were observed in the concentrations of N, P, Mg, Ca b, Fe and Al among the treatments. There were negative and not significant correlations between total N in tubers ($r = - 0.588$; $n = 20$; $R^2 = 34.8\%$) and leaves ($r = - 0.493$; ; $R^2 = 24.3\%$) with total tuber yields, indicating that increases in total N could be associated with reduced total tuber yields. The lowest total tuber yield (13.4 t/ha) was obtained in plants fertilized with 60 t/ha of chicken manure. The conclusion is that higher levels of chicken manure significantly ($p < 0.05$) increased nutrient concentrations in tubers and leaves, but reduced total tuber yields. Farmers are not advised to use high levels of chicken manure in sweetpotato production. Further research is required to determine the best levels of chicken manure that would be beneficial in sweetpotato production and human nutrition.

Keywords: Chicken, Sweetpotato, Swaziland.

INTRODUCTION

Organic farming is the form of agriculture that relies on the use of compost, green manure, and avoids the use of synthetic farm inputs. Land application of animal manure is an efficient utilization alternative because of lower costs compared to artificial fertilizer treatments: there are nutrient benefits derived by crops from manures [1]. Manure nutrients help build and maintain soil fertility. Manure can also improve soil tilth, increase water-holding capacity, lessen wind and water erosion, improve aeration, and promote beneficial organisms.

Manure contains plant nutrients and should be managed as a mixed fertilizer applied to satisfy crop nutrient needs. Alternate strategies are available to animal producers who have

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more manure than can be effectively applied based on nutrient needs. In many situations, relatively deep incorporation and intensive control of runoff at the application site can minimize environmental impact [1].

Raw chicken manure fertilizer can burn or kill plants if used because of the high level of ammonia that is produced during decomposition. Ammonia is released from fresh manure and during the process of anaerobic decomposition [2]. Composting chicken manure mellows the nitrogen and makes the manure suitable for the garden. A good soil amendment, chicken manure adds organic matter and increases the water-holding capacity and beneficial biota in soil [3].

Johnson, J., and Eckert, 2010 [1] reported that in animal manure management, phosphorus is the nutrient of major concern on soils with high phosphorus fertility levels; phosphorus applied to farms as manure or commercial fertilizer can move into bodies of water during erosion and runoff events, and is largely responsible for the accelerated eutrophication of many bodies of water in Ohio State (USA). The combined average percentage (per total mass) of aged chicken manure is about 1.8% nitrogen, 1.5% phosphate and 0.8% potash [4; 5]. In making manures, any sort of composting converts nitrogen into a form that a plant can use without burning the plant. Among the benefits of making composts from manure [5] is that composting destroys some bacteria including coccidian bacteria (associated with a chicken disease), worm eggs and viruses and stabilizes potash and nitrogen levels.

Whereas manures from all sources may be used for crop production, using pet and cat manures is not recommended in gardening. Unlike farm animal manures, pet manures do not readily break down or compost (it can take many months); dog and cat waste contains many unhealthy pathogens [6].

Regarding poultry manures uses, it was indicated [7] that although poultry manure can be burned for fuel or even reprocessed into food for other chickens and turkeys, it is most commonly used as fertilizer. The Physicians Committee for Responsible Medicine President Dr. Neal Barnard was cited [8] as calling on beef producers to voluntarily ban the practice of feeding chicken manure to cattle and also urged the U.S. Agriculture Department to investigate the health risks of the practice, which allegedly is most common in large poultry-producing States. Dr. Barnard was quoted as saying, "Chicken manure is filled with the disease-causing organisms, heavy metals and veterinary drugs that the chicken managed to expel. Unless the manure is carefully treated, using it in cattle feed supercharges a cow's intestinal tract with disease-causing bacteria that can be passed along to humans." Thus, there are concerns expressed about uses of chicken manures.

Other concerns about chicken manures involve heavy metal, especially lead and zinc concentrations. Zinc concentrations in tomato (*Lycopersicon esculentum* L.) and fruits were found to beat toxic levels (100-400 ug/g) as reported by [9]. Lead contents in all organs of two varieties of tomato under different treatments were more than the maximum amounts (5.0 ug/g), normal levels being 2.5 ug/g, and toxicity level for livestock being 30 ug/g according to [10]. Ramadan, and Adam, 2007 [11] concluded that these levels were higher than acceptable as safe for human consumption.

Regarding cost of manures, [12] reported that Iowa (USA) farmers appeared to adjust commercial fertilizer use based on whether they applied manure or not. For corn (*Zea mays* L.) following corn in a cropping system, Iowa farmers used 12% less nitrogen, and for corn after soybeans (*Glycine max* L.) they used 8% less. The change in fertilizer use produced a level of yield close to equivalent in 1996. The result was that costs, returns, and energy use were significantly improved with manure use. The study showed that, in practice, when using manure, fertilizer use and costs can be reduced without sacrificing crop yields or financial returns.

In Swaziland, Commercial fertilizers are too costly for sweetpotato farmers to buy, but with increased production of animal manures, especially chicken manure) animal waste is currently cheap and abundant for local farmers to obtain freely and use on their farm. However, it is not known what effects chicken manure might have on the concentration of nutrient elements in tubers and leaves of sweetpotato. Therefore this experiment was conducted to evaluate the effects of different levels of chicken manure on nutrient concentrations in sweetpotato tubers and leaves.

MATERIALS AND METHODS

Location and experimental design

This was a field experiment conducted in Malkerns Research Station, Malkerns, in Swaziland. Malkerns Research Station is located at 26.34°S, 31.10°E; it is 750 m above sea level, and has a mean annual temperature of 18°C. The mean annual rainfall range is 800-1,000 mm [13]. The soil was an Oxisol of the Malkerns soil series, described as dark loams to sandy loams [14]. The experimental design was a randomized complete block design which included five treatments and four replications. The treatments were: T_1, Control (no chicken manure applied); T_2, 20 t/ha of chicken manure; T_3, 40 t/ha of chicken manure; T_4, 60 t/ha of chicken manure; and T_5, a compound fertilizer, N:P:K. Each plot was 5.4 m long and 6.0 m wide; there were with seven ridges per plot.

Land preparation, soil sampling and liming

Table 1: Concentrations of nutrient elements in the chicken manure used in growing sweetpotato during the experiment

Parameter	Concentration
Moisture	8.3 (%)
Solids	91.7 (%)
Nitrogen	1.7 (%)
Phosphorus	1.4 (%)
Potassium	2.4 (%)
Sulfur	0.40 (%)
Magnesium	0.71 (%)
Calcium	6.7 (%)
Sodium	0.4 (%)
Aluminum	4047.0 (mg/kg)
Copper	76.0 (mg/kg)
Iron	4350.0 (mg/kg)
Manganese	681.0 (mg/kg)
Zinc	720.0 (mg/kg)

A tractor-mounted moldboard plow and disc harrow, respectively, were used in plowing and disking the land. Ridges (1.0 m apart) were made using a tractor-mounted ridger. To attain the appropriate shape of ridges, each ridge was later molded with hand hoes. The soil at the site was sampled (15-cm depth). The composite sample obtained was subjected to chemical analyses. According to liming recommendations for sweetpotato production in Swaziland, 1.17 tonnes/ha of dolomitic lime ($CaMgCO_3$) was applied by broadcasting on the ridges and incorporating into the ridges using hand hoes prior to planting. Anonymous, 1991 [15] recommended that in Swaziland, if soil pH is below 5.3, liming should be done.
The source of the chicken manure was a nearby commercial poultry farm. The chicken manure was "aged" [5] in an open-air space, beside the experiment site, for four weeks before being applied to the plots after planting. The chemical composition of the chicken manure that was used in the experiment is shown in Table 1.

Vine preparation and planting

'Kenya' variety of sweetpotato vines were obtained from a sweetpotato nursery plot at Malkerns Research Station. To insure good vine establishment, the day before planting all unfurled leaves were pruned from mature vines to reduce transpiration so that planted vines would not readily wilt. Using a pair of secateurs, each vine was cut to 30-cm lengths.
Sweetpotato vines were planted on 16 December, 2009. Each vine was 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.
After planting, the chicken manure and fertilizer treatments were imposed on the plots. At planting, the compound fertilizer [N-P-K, 2:3:2 (38)] that also contained 0.5% zinc, was applied at 350 kg/ha. At 6 weeks after planting (WAP), side dressing with 120 kg/ha was done

using 10 parts of urea (45% N) and 50 parts of muriate of potash, KCl (60% K) at a rate of 100 kg/ha. Fertilizer was applied by the banding and incorporation method.

Gap filling, irrigation, and weeding

Gap filling was done in all stands where vines did not sprout; this was done within 2 WAP, to ensure the desired plant population. Because rains were not regular, overhead sprinkler irrigation was used during the first WAP, once every two days. After vines had sprouted, irrigation frequency was reduced to once every week, depending on weather conditions. The soil was irrigated to field capacity on each occasion. General weeding was done at 4 and 8 WAP to reduce weed competition. The ridges were re-molded using hand hoes at the time of weeding.

Data collection and data analysis

Garden forks were used to harvest sweetpotato tubers 20 WAP. After yield determination, tubers and leaves were prepared for nutrient element determinations. From each plot, the terminal, unfurled 10 leaves of vines were collected in each plot. Their petioles were detached and the leaf blades from each plot were put into brown paper bags. Whole tubers were washed with clean water, and sliced into thin pieces to facilitate drying. All tuber and leaf samples (300 g each) were dried in a hot-air oven at 80°C [16] for four days. After drying, samples were ground in a mill and packaged in plastic bags; thereafter, they were sent by courier to a reputable commercial laboratory in the United States for chemical analysis using standard analytical methods [17]. Rainfall and temperature information was collected from Malkerns Research Station [18]. Data were analyzed using MSTAT-C statistical program, version 1.3 [19]; treatment means were separated using the least significant difference test [20] at 5% level of significance.

RASULTS

Meteorological information

Rainfall distribution and air temperatures are shown in Table 2. A total rainfall of 774.0 mm was received during the period of experiment. The lowest amount of rainfall (94 mm) and the highest amount (280 mm) fell in the months of March and June, respectively. Minimum (15.2°C) and maximum (28.2 C) temperatures were recorded in April 2010 and February 2010, respectively.

Tuber yields

As shown in Table 3, there were significant ($p < 0.05$) differences in the total tuber yield among the treatments at harvest. Plants fertilized with 350 kg/ha of compound fertilizer had non-significantly higher total yield (26.0 t/ha) than plants fertilized with no chicken manure (mean, 22.7 t/ha). There were no significant differences in the total tuber yield/plot among plants fertilized with 20 t/ha chicken manure (21.4 t/ha), and 40 t/ha of chicken manure (mean, 19.5 t/ha). The lowest total tuber yield was obtained in plants fertilized with 60 t/ha of chicken manure (mean, 13.3 t/ha).

Table 2: Rainfall and temperature during the experiment

Month/year	Monthly air temperature (°C)		Total rainfall (mm)
	Minimum	Maximum	
December 2009	17.0	27.3	**140.3**
January 2010	16.8	26.4	**280.8**
February 2010	18.6	28.2	**89.5**
March 2010	17.4	26.4	**94.4**
April 2010	15.2	24.8	**169.0**
Total	85.0	133.1	**774.0**
Mean	**17.0**	**26.6**	**154.8**

Source: [12]

Table 3: Tuber yields (t/ha) of sweetpotato associated with chicken manure or fertilizer.

Treatments	Marketable tuber yield (t/ha)	Non-marketable tuber yield (t/ha)	Total tuber yield (t/ha)
No chicken manure applied	17.7b	5.0b	**22.7b**
20 t/ha chicken manure	17.1ab	4.3ab	**21.4ab**
40 t/ha chicken manure	16.7ab	2.8ab	**19.5ab**
60 t/ha chicken manure	10.9a	2.4a	**13.3a**
Compound fertilizer	21.3b	4.7ab	**26.0b**
Means	**16.7**	**3.8**	**20.5**

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

Tuber nutrients

Table 4 shows that significant differences ($p < 0.05$) were observed in the concentrations of total N (0.5-1.2%); sulfur (0.60-0.11%); phosphorus (0.2-0.3%); and potassium (0.1-1.6%) in the tubers. Total nitrogen increased with increasing levels of chicken manure applied. When no chicken manure was used (control) total N was 0.5%, but increased to 1.2% when 60 t/ha of chicken manure was used for growing sweetpotato. There were no significant differences in the levels of nitrate nitrogen among the treatments. Among the micronutrients, only copper concentration was significantly ($p < 0.05$) different among the treatments. Table 5 shows the correlation matrix indicating various relationships among different tuber nutrient elements and sweetpotato tuber yield.

Leaf nutrients

As seen in Table 6, leaf nutrient elements showed significant ($p < 0.05$) increases in the levels of total N (3.8-4.2%); P (0.35-0.46%), as chicken manure increased. Levels of Mg (0.36-0.45%) and Ca (0.47-0.56%) significantly ($p < 0.05$) decreased with increasing levels of applied chicken manure. Among the micronutrients, boron (48.3-69.8 cmol/kg) and iron (71.3-120.8 cmol/kg) significantly ($p < 0.05$) decreased with increasing levels of chicken manure used. Aluminum (38.5-106.3 cmol/kg), though not an essential plant nutrient, had decreased concentrations with increasing levels of chicken manure application. Table 7 shows the correlation matrix indicating various relationships among different leaf nutrient elements and sweetpotato tuber yield.

Table 4: Concentrations of nutrient elements in sweetpotato tubers associated with chicken manure

Treatments	------------------ (%) ---------------								----------- (cmolc/kg) -------------					
	Total N	Nitrate N	S	P	K	Mg	Ca	Na	B	Zn	Mn	Fe	Cu	Al
No chicken manure applied	0.5	0.001	0.06	0.2	0.1	0.1	0.12	0.12	5.5	16.5	7.5	54.0	4.8	73.8
20 t/ha chicken manure	0.8	0.002	0.09	0.2	1.2	0.09	0.11	0.12	5.3	22.8	6.8	51.8	7.3	58.0
40 t/ha chicken manure	1.1	0.004	0.10	0.3	1.4	0.1	0.16	0.14	6.3	33.5	8.8	82.8	9.3	99.5
60 t/ha chicken manure	1.2	0.006	0.11	0.3	1.6	0.1	0.15	0.10	6.3	37.5	9.3	79.8	9.8	96.5
350 kg/ha fertilizer	0.6	0.001	0.07	0.2	1.1	0.09	0.11	0.13	5.3	18.0	7.3	69.5	5.3	84.5
Means	0.8	0.003	0.08	0.2	1.2	0.1	0.13	0.12	5.7	25.7	7.9	67.6	7.3	82.5
[1]LSD $_{(p < 0.05)}$	0.15	0.004	0.01	0.03	0.24	0.03	0.06	0.04	1.53	30.34	3.42	49.97	1.26	68.9
Significance	*	Ns	*	*	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns

[1]Least significance difference;

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

Table 5: Nutrient element concentrations in sweetpotato leaves of sweetpotato grown with chicken manure

Treatments	-------------------- (%) ------------------------								------------- (cmolc/kg) --------------					
	N	Nitrate N	S	P	K	Mg	Ca	Na	B	Zn	Mn	Fe	Cu	Al
No chicken manure applied	3.8	0.001	0.39	0.38	3.2	0.45	0.67	0.01	69.8	37.3	57.5	120.8	25.3	106.3
20 t/ha chicken manure	3.8	0.001	0.37	0.35	3.3	0.38	0.57	0.01	60.5	37.8	64.5	72.8	15.3	56.8
40 t/ha chicken manure	4.2	0.001	0.38	0.42	3.4	0.37	0.56	0.01	54.3	36.5	58.7	65.8	17.5	40.0
60 t/ha chicken manure	4.1	0.001	0.37	0.46	3.4	0.36	0.47	0.01	48.3	40.5	52.3	71.3	17.8	38.5
350 kg/ha fertilizer	3.6	0.001	0.35	0.32	3.1	0.39	0.55	0.01	62.8	31.0	66.0	73.5	14.3	54.3
Means	3.9	0.001	0.37	0.38	3.3	0.39	0.56	0.01	59.1	36.6	59.8	80.8	18.0	59.2
1LSD ($p < 0.05$)	0.28	0.001	0.031	0.07	0.35	0.042	0.11	0.00	13.06	8.17	17.71	34.12	14.33	40.21
Significance	*	Ns	Ns	*	Ns	*	*	Ns	*	Ns	Ns	*	Ns	*

[1]Least significance difference. * Significant at $P < 0.05$; and Ns, not significant

Table 6: Correlation matrix for the parameters measured in the chemical analysis of sweetpotato tubers and total tuber yield.

Parameters	Total N	Nitrate N	S	P	K	Mg	Ca	Na	B	Zn	Mn	Fe	Cu	Al
Nitrate N	0.733*													
S	0.944*	0.705*												
P	0.782*	0.527*	0.771*											
K	0.768*	0.435*	0.743*	0.698*										
Mg	0.520*	0.695*	0.575*	0.649*	0.312									
Ca	0.481*	0.595*	0.639*	0.377Ns	0.274	0.643*								
Na	- 0.195Ns	- 0.134Ns	- 0.294Ns	- 0.217Ns	- 0.309 Ns	- 0.166Ns	- 0.226 Ns							
B	0.376Ns	0.489*	0.433*	0.322Ns	0.341Ns	0.669*	0.580*	- 0.410Ns						
Zn	0.390Ns	0.299Ns	0.588*	0.471*	0.244Ns	0.429 Ns	0.811*	- 0.218Ns	0.267Ns					
Mn	0.436*	0.527*	0.456*	0.033Ns	0.379Ns	0.362 Ns	0.525*	- 0.312Ns	0.529*	0.16 Ns				
Fe	0.359Ns	0.576*	0.258Ns	0.299Ns	0.350Ns	0.366 Ns	0.256Ns	- 0.058Ns	0.341Ns	- 0.078Ns	0.250Ns			
Cu	0.939*	0.613*	0.925*	0.758*	0.812*	0.458*	0.541*	- 0.327Ns	0.357Ns	0.498*	0.486*	0.291Ns		
Al	0.281Ns	0.534*	0.195Ns	0.232Ns	0.334Ns	0.357Ns	0.247Ns	- 0.104Ns	0.398Ns	- 0.129Ns	0.298Ns	0.978*	0.253Ns	
Total tuber yield	- 0.588Ns	- 0.536Ns	- 0.581Ns	- 0.430Ns	- 0.679Ns	- 0.183Ns	- 0.308Ns	0.546*	- 0.461Ns	- 0.209Ns	- 0.401Ns	- 0.210Ns	- 0.622Ns	- 0.240Ns

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

Table 7: Correlation matrix for the parameters measured in the chemical analysis of sweetpotato leaves and total tuber yield.

Parameters	Total N	Nitrate N	S	P	K	Mg	Ca	B	Zn	Mn	Fe	Cu	Al
NO_3-N	0.516*												
S	0.567*	0.144 Ns											
P	0.770*	0.595*	0.419 Ns										
K	0.365 Ns	0.294 Ns	0.369 Ns	0.512*									
Mg	- 0.360 Ns	- 0.373 Ns	0.349 Ns	- 0.316 Ns	- 0.247 Ns								
Ca	- 0.081 Ns	- 0.299 Ns	0.496*	- 0.297 Ns	- 0.371 Ns	0.753*							
B	-0.260 Ns	- 0.466 Ns	0.406 Ns	- 0.555 Ns	- 0.358 Ns	0.583*	0.770*						
Zn	0.347 Ns	0.375 Ns	0.223 Ns	0.506*	0.473*	- 0.109 Ns	- 0.065 Ns	- 0.355 Ns					
Mn	- 0.507 Ns	-0.062 Ns	- 0.397 Ns	- 0.383 Ns	- 0.251 Ns	- 0.154 Ns	- 0.192 Ns	- 0.009 Ns	- 0.201 Ns				
Fe	- 0.219 Ns	- 0.189 Ns	0.434*	- 0.033 Ns	- 0.315 Ns	0.801*	0.576*	0.470*	- 0.224 Ns	- 0.011 Ns			
Cu	0.020 Ns	0.014 Ns	0.511*	0.282 Ns	0.233 Ns	0.284 Ns	0.090 Ns	0.198 Ns	0.024 Ns	- 0.008 Ns	0.534*		
Al	- 0.349 Ns	- 0.381 Ns	0.273 Ns	- 0.267 Ns	- 0.478 Ns	0.840*	0.661*	0.526*	- 0268 Ns	0.073 Ns	0.919*	0.315 Ns	
Total tuber yield	- 0.493 Ns	- 0.493 Ns	- 0.268 Ns	- 0.624 Ns	- 0.246 Ns	0.391 Ns	0.300 Ns	0.277 Ns	- 0.123 Ns	0.153 Ns	- 0.010 Ns	- 0.166 Ns	0.251Ns

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

DISCUSSION

Meteorological information

Fan *et al*., 2005 [21] showed that supplemental irrigation at a critical time could mitigate water stress and increase yields. The ecologically important environmental factors affecting plant growth include light, temperature and precipitation. It is likely that the yields and general performance of sweetpotato in this experiment could have been influenced by rainfall amounts and distribution received during the duration of the investigation.

Tuber yields

Onwueme and Sinha, 1991 [22] reported that nitrogen fertilizer delayed 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 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 [23]]. There were variations in marketable tubers due to wounds, with some tubers weighing outside the marketable mass range, as also previously reported [24].

Tuber nutrients

The Center for Science in the Public Interest ranked sweetpotato is considered as Number One in nutrition among all vegetables [25]. On evaluation, baked sweetpotato outscored other food materials, scoring 184 points. The next highest scored food (baked Irish potato) got a distant 83 points, falling behind sweetpotato by more than 100 points. The reasons for such a high rank for sweetpotato was because of its high concentration of dietary fiber, naturally occurring sugars, complex carbohydrates, protein, vitamins A and C, iron and calcium. Sweetpotato supplies important nutrients, as it is a source of energy, and is a natural source of dietary fiber [26]. The average sweetpotato tuber is low in cholesterol and sodium, virtually fat-free; it contains a lot of fibre. For this reason, many athletes consider sweetpotato as one of the top high-energy foods. Sweetpotato is also an excellent source of carotene, which the body converts into vitamin A. The Louisiana Sweet Potato Commission calls sweetpotato “the virtuous vegetable”[27]; this is because a medium-size sweetpotato also provides over 33% of the recommended daily vitamin C requirements. The ranges of nutrient elements recorded in this study were similar to those obtained in an earlier investigation [28]. Consumers that use sweetpotato tubers stand to benefit from such dietary advantages that sweetpotato provides.

Leaf nutrients

The leaves of plants contain the major portion of mineral elements found in plants. Sweetpotato leaves are commonly eaten and cooked as a salad in many countries because of the many nutrients contained in them. The concentration of nutrients in a plant depends on a number of factors: the age of the plant, the part of the plant sampled and the fertility level of the soil among other factors [29]. The mineral data obtained in this study will help human nutritionists develop healthier diets for the poor, malnourished inhabitants of developing countries.

Conclusion and Recommendation

This investigation established that though there are benefits of improved nutrient levels in tubers and leaves of sweetpotato, increasing levels of chicken manure application would lead to lowered sweetpotato yields. Further research is required to further investigate the role of chicken manure in sweetpotato production, including addressing concerns of heavy metal accumulation.

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