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Sweet potato (*Ipomoea batatas*) yield parameters, soil chemical properties and cost benefit ratios following incorporation of poultry manure and inorganic NPK fertilizers in low nutrient Ghanaian soils

K. Agyarko[1*], H. K. Dapaah[1], S. Buah[2] and K. A. Frimpong[3]

[1] *College of Agriculture Education, University of Education, Winneba, Mampong-Ashanti, Ghana*

[2] *CSIR-SARI, Wa, Ghana*

[3] *Department of Soil Science, University of Cape Coast, Cape Coast, Ghana*

ABSTRACT

The impact of sole poultry manure (6t PM ha^{-1}), sole NPK (200kg NPK ha^{-1}) and their combinations (3t PM + 100kg NPK ha^{-1} and 1.5t PM + 150kg NPK ha^{-1}) on sweet potato yield parameters and soil nutrients was assessed at Adiembra and Fiaso in Ghana between June, 2011 to November, 2011 using RCBD. Nutritional levels of the sweet potato tubers and the amended soils were analysed with standard laboratory procedures. The 3t PM + 100kg NPK ha^{-1} produced significantly (p=0.05) the highest tuber yield (tonnes ha^{-1}), tuber length and diameter, and also had the highest percentage of marketable tubers. The total percentage soil nitrogen, organic matter, Total Base Saturation (TEB) and Effective Cation Exchange Capacity (ECEC) were significantly (p=0.05) highest in the 6t PM ha^{-1} treatment. The 6t PM ha^{-1} treatment had the highest tuber nutrient values for Ca, Mg, P, S and N. The 3t PM + 100kg NPK ha^{-1} had the highest cost benefit ratios of 1:4.38 and 1:8.15 at Adiembra and Fiaso respectively. The results demonstrated that combined application of PM and NPK increased sweet potato tuber yield and soil nutrient levels in a cost effective manner.

Keywords: Soil amendment; poultry manure; NPK; sweet potato; cost benefit ratio

* Corresponding author: Tel.: 233 244040932; E-mail: agyarkokofi@yahoo.com

1. INTRODUCTION

The competition for land is becoming intense with the continuous rise in human population and thus resulting in the continuous use of land for farming year after year. Consequently, the traditional shifting cultivation that was hitherto used to ensure that crops obtain adequate soil nutrient supply to promote maximum yield have become unsustainable. Therefore, adoption of more sustainable strategies for the maintenance of soil fertility under such conditions becomes imperative to sustain crop yield. Inorganic fertilizers which in the past years, have proved to be effective in restoring soil fertility has its own problems [1]. Apart from the aftermath effect of continuous use of inorganic fertilizers, they are expensive for the resource-poor, small scale crop farmer in the sub-Saharan African region to purchase [2].

Organic manure can be used as an alternative nutrient input . Although the nutrient content of organic materials are relatively lower than in inorganic fertilizers, they have the additional property of improving the physical properties of the soil: Thus physical soil characteristics such as water infiltration rate, tilth, water holding capacity, and aeration, are generally improved by the addition of organic manure. The biological characteristics of soil, such as biomass, biological activity, and biodiversity, can also be improved through organic manures [3, 4].

Studies have shown that combined application of inorganic and organic fertilizers have resulted in significant increases in crop yield and increases in soil nutrients as compared with sole application of inorganic fertilizers [5, 6, 7, 8, 9]. Such fertilizer combinations have also been found to be efficient economically [10, 11].

So far only a few of the sweet potato farmers in the study areas, Fiaso and Adiembra in the Brong-Ahafo region and Ashanti region respectively in Ghana use fertilizers in their farming activities. Although poultry manure and cow-dung are within the reach of these farmers they do not use them as sources of fertilizer. The objectives of the study was to investigate the benefits of using both inorganic and organic fertilizers in improving the tuber yield and nutrient contents of sweet potato tubers, soil properties and the financial implications of combined use of organic and inorganic fertilizers in small scale potato farming enterprise.

2. MATERIAL AND METHODS

The study was carried out in two sites: Fiaso (Long. 1°55'45"W and Lat. 7°34'38"N) in the Techiman municipality and Adiembra (Long. 1°22'00"W and Lat. 7°22'59"N) in the Ejura municipality between June, 2011 to November, 2011. The two sites are located in the transitional zone of the semi-deciduous rainforest and the guinea savannah agroecological zones of Ghana, respectively.

Poultry manure (PM) which had been kept in jute bags for two weeks under a shade and inorganic fertilizer -N:P_2O_5:K_2O (NPK – 15:15:15) were used to amend soils at the two sites. The treatments included; Control (No soil amendment), 6tPM ha^{-1}, 200kgNPK ha^{-1}, 3tPM + 100kgNPK ha^{-1} and 1.5tPM + 150kgNPK ha^{-1}.

Treatments were incorporated (soil depth of ≤ 15cm) on ridges of size 0.5m x 5m separated from each by a distance of one meter. Each experimental plot was made up of three of the ridges. At each site the treatments were replicated three times and assigned randomly (using RCBD) to the plots. Vines of sweet potato ‘Ogyefo’-variety with purple skin were planted on the ridges two weeks after the application of the PM. Vines were planted at an interval of 30cm on the ridges, leading to a plant population of 18,000 ha^{-1}. The inorganic fertilizer was applied in split form, one month after planting and two months after planting respectively. The study was done under rain-fed conditions to simulate farmers’ practice. Harvesting was done four months after planting.

By means of a top loaded scale the fresh weight of sweet potato tubers harvested from each treatment was recorded. Tuber diameter and length were assessed with the help of a veneer caliper.

The nutrient contents of soils (0-15cm) of treatments and the sweet potato tubers (selected from the middle row of plots) washed and cut into chips were analysed at the laboratory of Soil Research Institute, Kumasi, Ghana, soon after harvesting. The background soil properties (Table 1) were also determined in the same laboratory.

The total Nitrogen and Phosphorus were determined by the Micro Kjeldahl and the colorimetric methods respectively [12]. Nitrate-N was determined by the phenoldisulphonic acid method [13]. Available P was determined by the Bray 1 method, and the total and exchangeable calcium and magnesium were determined by EDTA titration method, while potassium and sodium were assessed using a flame photometer [14]. The pH (H_2O) of the soil samples was also measured [15]. Particle size distribution was carried out by the hydrometer method while organic carbon was determined by the Walkley-Black method [14].

Data were subjected to analysis of variance (ANOVA) and means were compared using the Duncan's Multiple Range Test (DMRT) of the MSTAT-C statistical software package [16].

3. RESULTS AND DISCUSSION

The chemical and physical properties of the soils used in the two experimental sites are presented in Table 1. The soils were sandy loam and acidic. Based on previous studies [17] the organic C and total N of the soils were not adequate, however, Ca, K and available P have values enough for the production of crops in the sub region. The values of the nutrients in the PM used in the study (Table 2) have been considered as ideal in soil amendments for the growth of tuber crops [18].

Sweet potato tubers, tuber length and diameter were significantly higher in the amended soils than the control treatment (Table 3). Treatment combinations of NPK and PM amendment produced the highest tonnage of sweet potato tubers, tuber length and diameter at the two experimental locations. The 3t PM + 100kg NPK ha^{-1} treatment had the highest values of the yield parameters with the 1.5t PM + 150kg NPK ha^{-1} treatment recording the second highest figures at both locations of the experiment. In a similar study the combination of farm yard manure (2 t ha^{-1}) and triple super-phosphate (30 kg P ha^{-1}) produced the highest potato tuber yield (20.58 t ha^{-1}) among the sole treatments and the control [19]. A study [20] has also found combined fertilizers to produce significantly higher potato tuber yield (20.8t ha^{-1}) than all other treatments. In other studies as observed in the current study the combined treatments of organic and inorganic fertilizers have been found to produce the highest levels of some growth and yield parameters of some selected crops [21, 22, 23] compared to the sole applications of either inputs.

Tables 4 and 5 indicate the nutrient levels of the soils at the experimental stations after harvesting the sweet potatoes. The application of the treatments brought changes in the soil nutrient levels at both locations. The nutrient levels of the amended soils were all higher than the unamended soils. The sole PM treatment (6t PM ha^{-1}) recorded significantly ($P=0.05$) the highest values of total percentage nitrogen, organic matter and exchangeable cations. The 3t PM + 100kg NPK ha^{-1} and the 1.5t PM + 150kg NPK ha^{-1} treatments had values next to the 6t PM ha^{-1} in that order at both locations. The application of sole PM as soil amendment has proven to perform better than other treatments in other experiments in the enhancement of soil nutrients as observed above. Organic matter, K, Ca and Mg levels have been found to be higher in a soil amended with a sole PM than the combined treatment of PM and NPK in a growth and yield study of tomato in Nigeria [24]. Similar studies [18] also found, the organic matter content, N and Mg levels in a Nigerian soil to be higher after amendment with a sole PM than the combined treatment of PM and NPK in a comparative evaluation studies of PM and NPK fertilizer studies.

The Total Base Saturation (TEB) and the Effective Cation Exchange Capacity (ECEC) which are the reflections of the Exchangeable Cations were also significantly highest in the 6t PM ha^{-1} treatment with the other combined treatments following in suit. Though the nutrient levels under the sole PM treatment were the highest, the 3t PM + 100kg NPK ha^{-1} treatment gave the highest tuber yields in all the experimental sites, this might due to the combined positive interactive effect of the properties of the 3t PM + 100kg NPK ha^{-1} treatment.

Generally the nutrient levels of the sweet potato tubers from the amended soils were higher than those from the control (Table 6). Tubers from the 6t PM ha^{-1} treatment had the highest nutrient values for Ca, Mg, P, S and N, with value from the combined treatments of 3t PM + 100kg NPK ha^{-1} and the 1.5t PM + 150kg NPK ha^{-1} following in the order of the soil nutrient levels as found in Tables 4 and 5. Such observations are not uncommon as previous experiments have shown positive correlations between soil nutrients and plant tissue nutrients content [25, 26, 27].

For farmers to appreciate the benefits of combined application of easily available poultry manure and the relatively expensive inorganic NPK fertilizer in crop production, the cost benefit ratios associated with using the afore-mentioned inputs in the current study were estimated. The 3t PM + 100kg NPK ha^{-1} treatment earned a revenue of GH¢3777 with the cost of production of GH¢1119 and a higher cost benefit ratio (1:4.38) at the Adiembra site while the same 3t PM + 100kg NPK ha^{-1} treatment earned a revenue of GH¢8040 with the cost of production of GH¢1124 and a higher cost benefit ratio (1:8.15) at the Fiaso site (Table 7).

The combinations of the PM and the NPK in soil amendments proved to be more cost effective in the production of sweet potato than the sole application of NPK or poultry manure or where no amendment is made.

4. CONCLUSION

It could be concluded that the tuberous root yield components of sweet potato was significantly enhanced in response to the application of the combinations of the PM and the NPK in soil amendments (3t PM + 100kg NPK ha^{-1}) in the study areas. The 3t PM + 100kg NPK ha^{-1} also proved to be more cost effective in the production of sweet potato than the sole application of NPK or PM or where no amendment is made, thus indicating that enriching the soil with organic matter and inorganic fertilizers together holds the key for maximizing the yield of sweet potato crop in the study areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

All the work of the paper was carried out among the authors. All the authors made corrections, read and approved for final publication mutually.

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Table 1. Chemical and physical analysis of soils used for the study at Fiaso and Adiembra

Parameter	Fiaso	Adiembra
pH	5.70	5.80
Organic M (%)	1.13	1.15
Total nitrogen (%)	0.08	0.08
Available phosphorus (mg kg^{-1})	11.01	12.92
Exchangeable K (cmol kg^{-1})	0.27	0.30
Exchangeable Ca (cmol kg^{-1})	2.42	2.63
Exchangeable Mg (cmol kg^{-1})	1.59	1.91
Exchangeable Na (cmol kg^{-1})	0.48	0.50
Sand (%)	77.50	62.52
Silt (%)	14.50	33.48
Clay (%)	8.00	4.00
Soil textural class	Sandy loam	Sandy loam

Table 2. Chemical analysis of poultry manure used for the study

Organic manure	Organic C (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Poultry manure	31.43	3.08	1.29	0.88	0.76	0.50

Table 3. Effect of levels of poultry manure and NPK fertilizer on yield parameters of sweet potato

Treatment (ha^{-1})	Weight of tubers ($t\ ha^{-1}$)		% Weight of marketable tubers		Tuber Length (cm)		Tuber Diameter (cm)	
	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra
Control	8.09 d	5.58 c	71.54	67.64	13.80 c	9.36 c	5.40 c	4.23 b
6t PM	14.88 c	11.06 ab	76.78	68.42	14.70 bc	13.65 ab	5.93 bc	5.22 ab
200kg NPK	13.09 c	10.33 b	75.55	68.18	14.60 bc	13.30 b	5.78 bc	4.52 b
3t PM + 100kg NPK	22.91 a	12.24 a	85.19	90.24	17.13 a	14.40 a	7.00 a	5.82 a
1.5t PM + 150kg NPK	17.85 b	11.48 ab	78.70	70.09	15.43 b	14.34 a	6.33 ab	5.28 ab

Values followed by the same letter(s) in the columns are not significant at P=0.05 (DMRT)

Table 4. Soil nutrient levels after sweet potato harvest at Fiaso

Treatment (ha^{-1})	pH (1:1-Soil: H_2O)	Total N %	Org M %	Exchangeable Cations Me/100g				TEB	Exch A (Al+H)	ECEC	Base Sat. %
				Ca	Mg	K	Na				
Control	5.66a	0.08b	1.13c	2.40c	1.60c	0.20a	0.45b	4.65d	0.66a	5.31e	87.57c
6t PM	5.27a	0.11a	1.53a	3.74a	2.94a	0.28a	0.53a	7.69a	0.48c	8.17a	94.12a
200kg NPK	5.62a	0.09ab	1.16c	2.40c	1.65c	0.24a	0.45b	4.74d	0.65ab	5.39d	87.94c
3t PM +100kg NPK	5.45a	0.10ab	1.48ab	3.20ab	2.00b	0.26a	0.48ab	5.94b	0.58b	6.52b	91.10b
1.5t PM +150kg NPK	5.61a	0.09ab	1.36b	2.94bc	1.98b	0.24a	0.47ab	5.63c	0.60ab	6.23c	90.37b

Values followed by the same letter(s) in the columns are not significant at P=0.05 (DMRT)

Table 5. Soil nutrient levels after sweet potato harvest at Adiembra

Treatment (ha^{-1})	pH (1:1-Soil:H_2O)	Total N %	Org M %	Exchangeable Cations Me/100g				TEB	Exch A (Al+H)	ECEC	Base Sat. %
				Ca	Mg	K	Na				
Control	5.77a	0.07c	1.16c	2.65d	1.88b	0.28b	0.47d	5.28e	0.45a	5.73d	92.15c
6t PM	5.95a	0.13a	1.47a	3.98a	2.94a	0.50a	0.59a	8.01a	0.30b	8.31a	96.39a
200kg NPK	4.60b	0.10b	1.20c	2.67d	1.90b	0.40a	0.48cd	5.45d	0.41ab	5.86d	93.00bc
3t PM + 100kg NPK	5.47ab	0.12ab	1.40ab	3.74b	2.68a	0.48a	0.51b	7.41b	0.38ab	7.79b	95.12ab
1.5t PM + 150kg NPK	5.66a	0.11ab	1.38b	3.10c	2.14b	0.43a	0.50bc	6.17c	0.40ab	6.57c	93.91abc

Values followed by the same letter(s) in the columns are not significant at P=0.05 (DMRT)

Table 6. Nutrient levels of sweet potato tubers at the two experimental sites

Treatment (ha^{-1})	Ca (%)		Mg (%)		P (%)		K (%)		N (%)	
	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra
Control	0.15a	0.13b	0.09c	0.14d	0.10d	0.12c	0.53a	0.44b	0.49e	0.95c
6t PM	0.20a	0.19a	0.22a	0.24a	0.17a	0.19a	0.62a	0.56a	0.84a	1.19a
200kg NPK	0.16a	0.15ab	0.15b	0.17c	0.12cd	0.15b	0.56a	0.48a	0.60d	1.02bc
3t PM + 100kg NPK	0.18a	0.17ab	0.20a	0.21b	0.15ab	0.18ab	0.60a	0.50a	0.77b	1.19a
1.5t PM + 150kg NPK	0.16a	0.17ab	0.19a	0.18c	0.13bc	0.17ab	0.58a	0.49a	0.67c	1.09ab

Values followed by the same letter(s) in the columns are not significant at P=0.05 (DMRT)

Table 7. Economic analysis of organic and inorganic fertilizers on the yield of sweet potato

Treatment (ha^{-1})	Yield (kg ha^{-1})		Value of yield (GH¢ ha^{-1})		Cost of production (GH¢ ha^{-1})		Net benefit (GH¢ ha^{-1})		Cost-benefit ratio	
	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra	Fiaso	Adiembra
Control	8090	7580	3236	2232	823	823	2413	1409	1:3.93	1:2.71
6t PM	14880	11480	5952	4592	1066	1124	4886	3468	1:5.58	1:4.09
200kg NPK	13090	10330	5236	4152	1119	1066	4117	3066	1:4.68	1:3.88
3t PM + 100kg NPK	22918	12240	9164	4896	1124	1119	8040	3777	1:8.15	1:4.38
1.5t PM + 150kg NPK	17850	11060	7140	4424	1046	1046	6094	3378	1:6.83	1:4.23

Note: 1 USD = 1.9400 GH¢