INTEGRATED SOIL NUTRIENT MANAGEMENT OPTION FOR SUSTAINABLE YAM PRODUCTION

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ABSTRACT

A study was conducted at the on-station in Fumesua (Forest) and Ejura (Forest-Savannah transition) of Ghana to evaluate integrated soil nutrient management approach on soil and yam productivity. A split-factorial design with two preceding systems (Pigeon pea and Yam) as main plot treatments and a factorial of poultry manure (0, 3 and 6 t ha^{-1}) and chemical fertilizer (0, 15 - 15 - 20, and 30 - 30 - 40 kg ha^{-1} N-P_2O_5-K_2O) as subplot treatments. The results of the study revealed significant ($P \leq 0.05$) interaction between preceding system, poultry manure and chemical fertilizer on fresh tuber yields. When yam followed pigeon pea as preceding crop, tuber yields were higher, and yields from 3 t ha^{-1} poultry manure and 15 - 15 - 20 kg ha^{-1} N-P_2O_5-K_2O were similar to yields when manure and chemical fertilizer were doubled to 6 t ha^{-1} and 30-30-40 kg ha^{-1} N-P_2O_5-K_2O. Also when yam followed pigeon pea, the cost benefit ratio showed that Gh₵ 1.00 farmer investment in yam production resulted a profit of Gh₵ 1.65 and Gh₵ 2.22 in addition to the Gh₵ 1.00 invested capital for both Fumesua and Ejura communities respectively. The study suggests integrated nutrient management approach with preceding systems such as pigeon pea (16,667 plants ha^{-1}) and 3 t ha^{-1} poultry manure would reduce the chemical fertilizer requirement to a third for sustainable yam production on continuously cropped fields.

Key words **:** Integration, legumes, climate change, Ghana.

RESUME

APPROCHE INTEGREE DE GESTION DES NUTRIMENTS DU SOL POUR UNE PRODUCTION DURABLE DE L'IGNAME

Une étude a été menée à la station de Fumesua (Forêt) et Ejura (zone de transition Forêt-Savane) au Ghana pour évaluer l'approche intégrée de gestion des éléments nutritifs du sol sur la productivité du sol et de l'igname. Un plan factoriel fractionné avec deux systèmes précédents (Pois de cajan et Igname) comme traitement principal de parcelle et une factorielle de fumier de volaille (0, 3 et 6 t ha^{-1}) et d'engrais chimique (0, 15 - 15 - 20, et 30 - 30 - 40 kg ha^{-1} N-P_2O_5-K_2O) comme traitements de sous-parcelles. Les résultats de l'étude ont révélé une interaction significative ($P < 0,05$) entre le système précédent, le fumier de volaille et l'engrais chimique sur les rendements de tubercules frais. Lorsque l'igname suit le pois cajan comme culture précédente, les rendements des tubercules sont plus élevés et les rendements de 3 t ha^{-1} obtenus avec du fumier de volaille et avec de l'engrais chimique à 15 - 15 - 20 kg ha^{-1} N-P_2O_5-K_2O étaient semblables aux rendements lorsque le fumier et l'engrais chimique sont doublés à 6 t ha^{-1} et 30 - 30 - 40 kg ha^{-1} N-P_2O_5-K_2O. De même, lorsque l'igname suit le pois cajan, le rapport coût-bénéfice montre qu'un investissement de 1,00 ₵Gh dans la production d'igname génère un bénéfice de 1,65 ₵Gh et 2,22 ₵Gh en plus du capital investi de 1,00 ₵ Gh respectivement pour les communautés Fumesua et Ejura. L'étude suggère une approche intégrée de gestion des nutriments avec des systèmes précédents tels que le pois cajan (16 667 plants ha^{-1}) et 3 t ha^{-1} de fumier de volaille réduirait les besoins en engrais chimiques d'un tiers pour la production durable d'igname sur les champs cultivés en continu.

Mots clés: *Intégration, légumineuses, changement climatique, Ghana.*

INTRODUCTION

Yam is an important staple food crop and currently a major non-traditional export crop in Ghana. It is one of the two major root crops produced and consumed in Ghana and West Africa. For the past decade, yam production in Ghana has ranked third in the world and contributes about 16 % to the National Agricultural Gross Domestic Product (FAOSTAT, 2006). However, the major challenge to yam production is soil fertility regeneration and maintenance. Farmers address this constraint by clearing new areas on yearly basis in search of fertile lands leading to deforestation and soil degradation (Ennin *et al.*, 2014). Yam is a heavy soil nutrient feeder; a ton of yam is reported to extract 3.8 - 4.0 kg ha^{-1}, 0.39 - 1.1 kg ha^{-1}, 4.2 - 5.9 kg ha^{-1} of N, P_2O_5 and K_2O respectively (Ferguson and Haynes, 1970 ; Le Buanec, 1972). The struggle for fertile lands coupled with the increasing human population has led to pressure on cropland and forestlands in the prevailing yam growing communities (Asante, 1996 ; Akwag *et al.*, 2000). As a result, the distances to typical fields farmers would normally want to use for yam production are very far and more difficult to access thereby increasing the drudgery associated with yam production. Farmers are increasingly compelled to grow yam on non-fallowed land leading to reduced yields (Akwang *et al.*, 2000 ; EPA, 2003; Ennin *et al.*, 2012). Therefore, the maintenance of soil fertility with mineral fertilizer seems to be a viable means of addressing the problem. Ennin *et al*. (2014) suggested an optimum fertilizer rate of 45 - 45 - 60 kg ha^{-1} N-P_2O_5-K_2O on continuously cropped fields for the major yam growing areas of the forest-savannah transition zones of Ghana. However, in many cases, the use of mineral fertilizer alone has not promoted good soil health (Kotschi *et al*., 1988). In addition, it is becoming increasingly difficult for poor-resource farmers who earn less than US $1per day to meet the fertilizer requirements on their farms. For these reasons, greater attention is being paid to alternative ways of sustaining the soil for yam and other crop production (Subba RaO, 1980). Although traditional organic materials such as crop residues and animal manure are found to be cheap sources, their availability in most cases are limited in supply to offer a real alternative (Kotschi *et al.,* 1988 ; Young, 1997 ; Diby, 2011). The use of legumes has been identified as a major constituent in sustainable cropping systems due to their biological nitrogen fixation (Asafu-Agyei *et al*., 1997; Kombiok *et al*., 1997; Ennin *et al*., 2004) and therefore can be adopted and used in sustainable yam production.

The study hypothesis that an integrated soil nutrient management approach with mineral fertilizer, organic manure and leguminous preceding system would offer environmentally friendly and affordable option of sustaining the soil for yam production. This paper presents the results from 2010 to 2013 at the on station with the goal of investigating chemical fertilizer and integrated soil nutrients management approach options for sustainable yam production. Specifically to evaluate the effect of chemical fertilizer, preceding system and poultry manure on the growth and yields of yam.

MATERIAL AND METHODS

The study was conducted at Fumesua in the forest and Ejura in the forest-savanna transition agro-ecologies of Ghana (Table 1). The experimental design was split plot-factorial combination with three replications. Preceding System (Pigeon pea and Yam) as the main plot treatments and 3×3 factorial of Poultry Manure (0, 3 and 6 t ha^{-1}) and mineral fertilizer (0-0-0, 15 - 15 - 20 and 30 - 30 - 40 ; kg ha^{-1} N-P_2O_5–K_2O) as sub plot treatments. The preceding system (Pigeon pea and Yam) treatment was planted in the major season of 2009. The pigeon pea planted at 16,667 plants ha^{-1} whiles the yam at 6,944 plants ha^{-1} and cultivated on the fields for 2 seasons. The poultry manure treatments were applied in major growing season of 2011 just before the planting of the yam. The mineral fertilizer treatments were applied 11 - 12 weeks (bulking stage of the yam) after planting of the yam. The study was repeated in the 2012 growing seasons for verification of findings. All plots were ploughed and harrowed after which manual ridges of 40 - 45 cm high were constructed in rows. Each plot had an area of 144 m^2 with ten rows of ridges and 1.2 m between them with yam planted at 1.2 m between them on each ridge. The data were collected on growth and yield performance of the yam and subjected to analysis of variance at 5 % significant level using SAS, 2007 version. Inputs and out puts of each the treatment were used for partial budgeting as the economic analysis.

Table 1 : Agro-ecological characteristics of the site

Caractéristiques agro-écologiques du site

Characteristics	Location Fumesua (6° 41' N, 1° 28' W)	Ejura (7° 23' N, 1°21' W)
Agro-ecological zone	Humid Forest	Forest-Savannah Transition
Soil type	Ferric Acrisol; Asuasi series upper top soil consisted of 5cm greyish brown sandy loam topsoil of dark brown gritty clay loam	Ferric Lixisol; Ejura series with 20-30cm thick top layer of loam soils. Soils are dark brown to brown fine sandy loam
Temperature (Min-Max. °C) 2009-2012	21-31	21-34
Wet season	Bimodal rainfall pattern	Bimodal rainfall pattern
Major	March –mid August	March –mid- August
Minor	Sept-Nov; peak in Oct	September- Nov; peak in Oct
Total annual rainfall (mm) 2009 -2012	1027-1322 averaging 1184mm/yr	1171-1574; averaging 1313mm/yr

Adopted from Adu and Asiamah (1992)

RESULTS

INFLUENCE OF PRECEDING SYSTEM ON STAND ESTABLISHMENT

Figure 1a et 1b report the Stand Count 33 Days After planting and at Harvest as influemced by Preceding system, poultry manure and chemical fertilizer respectively at Fumesua and Ejura. The results showed no significant (P > 0.05) differences in the number of stands count in Days after planting and at harvest for continuously cropped field and fields preceded by pigeon pea irrespective of the location.

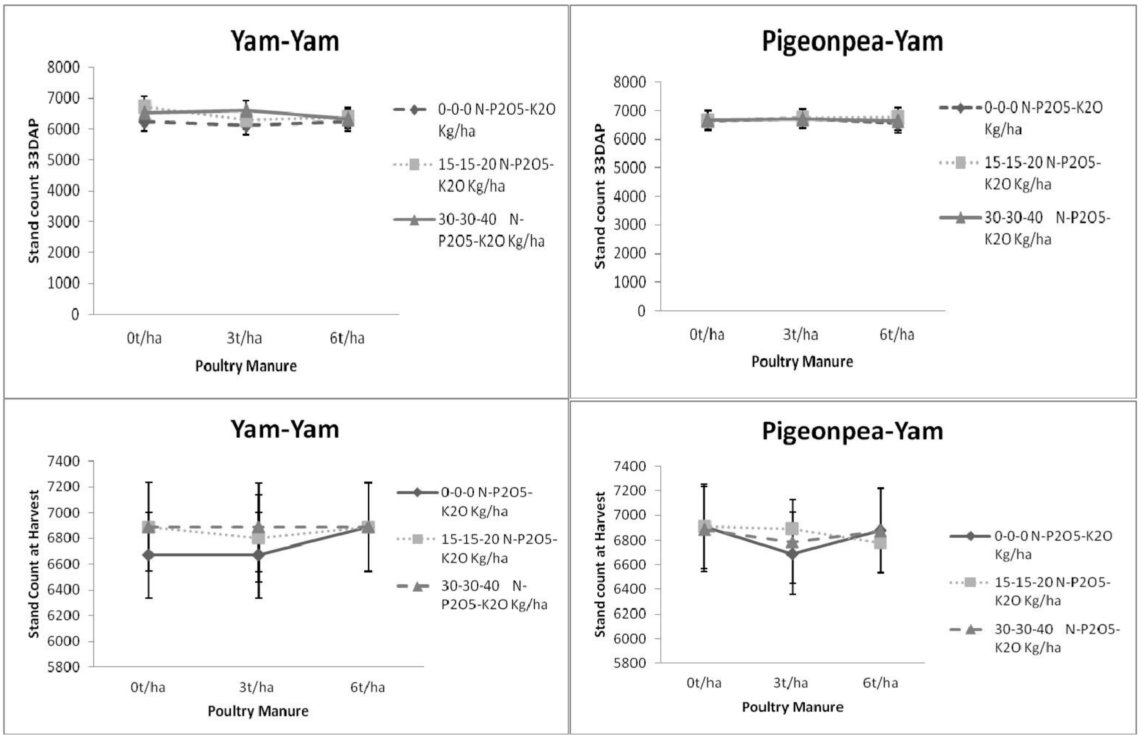

Figure 1a : Stand Count 33 Days After planting and at Harvest as influemced by Preceding system, poultry manure and chemical fertilizer at Fumesua, Ghana

Nombre de peuplements 33 jours après le semis et à la récolte, selon l'influence du système précédent, fumier de volaille et engrais chimique à Fumesua, au Ghana

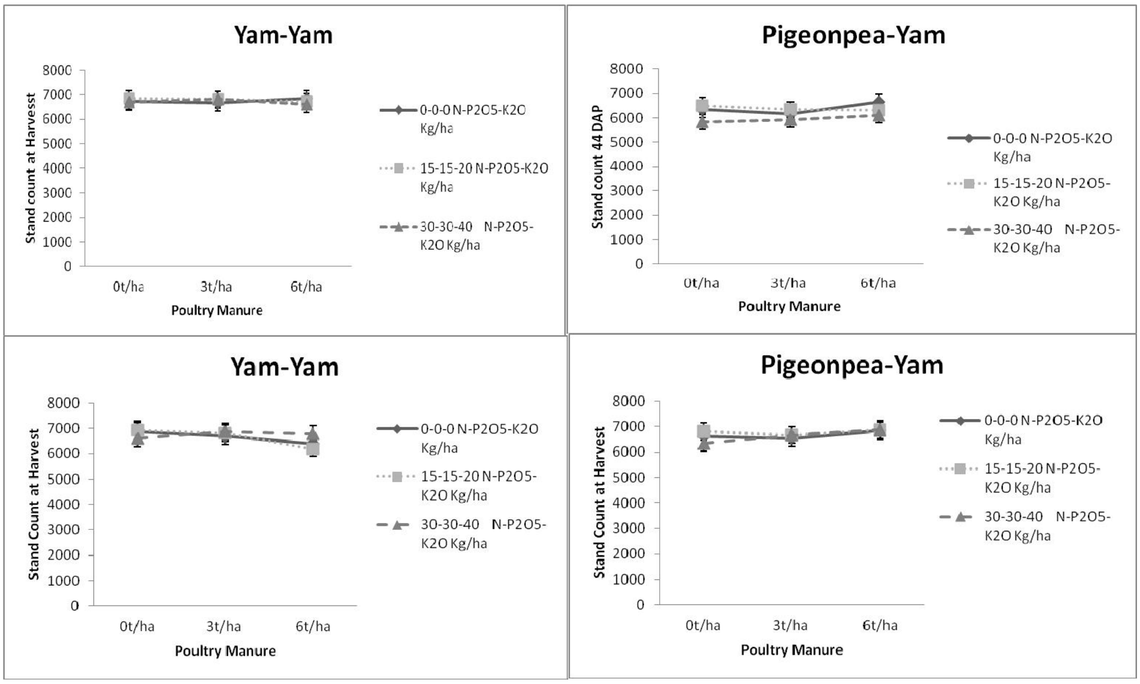

Figure 1b : Stand Count 44 Days After planting and at Harvest as influemced by Preceding system, poultry manure and chemical fertilizer at Ejura, Ghana

Nombre de peuplements 44 jours après le semis et à la récolte, selon l'influence du système précédent, fumier de volaille et engrais chimique à Ejura, au Ghana

INFLUENCE OF PRECEDING SYSTEM ON FRESH TUBER YEILD

Studies in Fumesua and Ejura in the forest and forest-savanna transitional zones of Ghana, respectively, indicate the potential of pigeonpea in improving soil fertility and farm profitability (Figure 2a, 2b, 2c 2 and 2d). The yam tuber yields were significantly ($P \leq 0.05$) influenced by the interaction between the preceding system, poultry manure and chemical fertilizer. The yam tuber yield on fields preceded by pigeon pea with 3 t ha^{-1} poultry manure and 15 - 15 - 20 kg ha^{-1} N-P_2O_5-K_2O was similar to yields when manure and chemical fertilizer were doubled to 6 t ha^{-1} and 30 - 30 - 40 kg ha^{-1} N-P_2O_5-K_2O. Thus, irrespective of the location and the preceding system the yield differences were not significant ($P > 0.05$) between the fields which received the different rates of poultry manure (3 t ha^{-1} and 6 t ha^{-1}) and chemical fertilizer (15-15-20 & 30-30-40 kg ha^{-1} N-P_2O_5-K_2O) (Fig 2a, 2b, 2c and 2d).

Fields preceded by pigeon pea with poultry manure and chemical fertiliser had significantly high organic matter and content. Fields where the poultry manure and chemical fertilizer where doubled to from 3t ha^{-1} and 15-15-20 N-P_2O_5-K_2O to 6t ha^{-1} and 30-30-40 kg ha^{-1} N-P_2O_5-K_2O respectively had similar pH, organic carbon and matter contents (Fig. 3 and 4). When yam preceded yam the presence of the poultry manure were still significant on the soil organic carbon and matter content (Fig. 3).

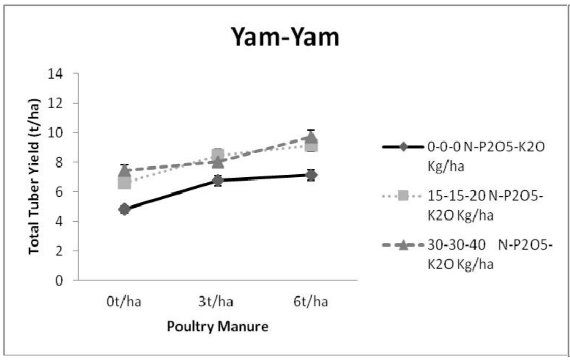

Figure 2a : Yield of yam as influemced by poultry manure and chemical fertilizer on a field preceded by yam, Fumesua, Ghana

Rendement de l'igname influencé par le fumier de volaille et l'engrais chimique sur un champ précédé par de l'igname, Fumesua, Ghana

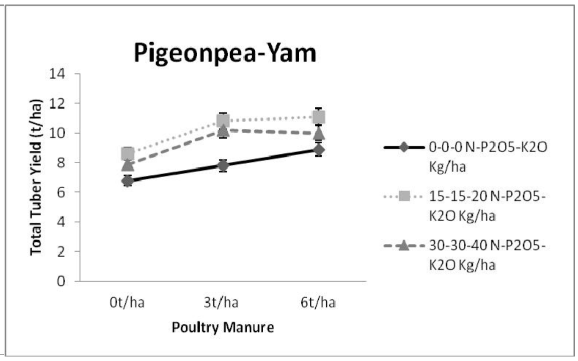

Figure 2b : Yield of yam as influemced by poultry manure and chemical fertilizer on a field preceded by pigeonpea, Fumesua , Ghana

Rendement de l'igname influencé par le fumier de volaille et l'engrais chimique sur un champ précédé par du pois cajan, Fumesua, Ghana

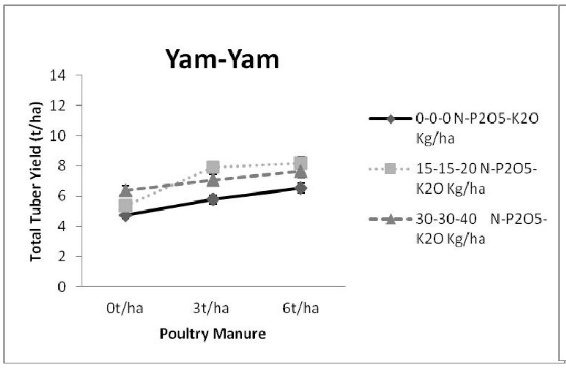

Figure 2c : Yield of yam as influemced by poultry manure and chemical fertilizer on a field preceded by yam, Ejura, Ghana

Rendement de l'igname influencé par le fumier de volaille et l'engrais chimique sur un champ précédé par de l'igname, Ejura, Ghana

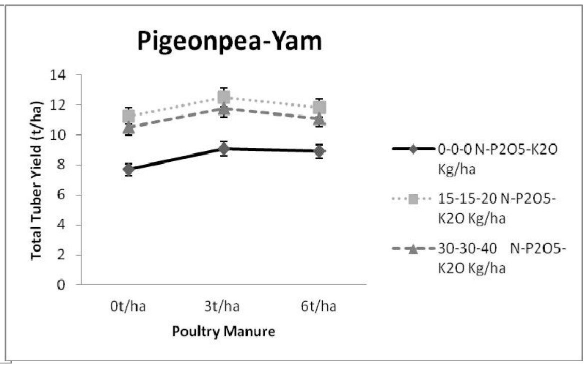

Figure 2d : Yield of yam as influemced by poultry manure and chmeical fertilizer on a field preceded by by pigeonpea, Ejura, Ghana

Rendement de l'igname influencé par le fumier de volaille et l'engrais chimique sur un champ précédé par du pois cajan, Ejura, Ghana

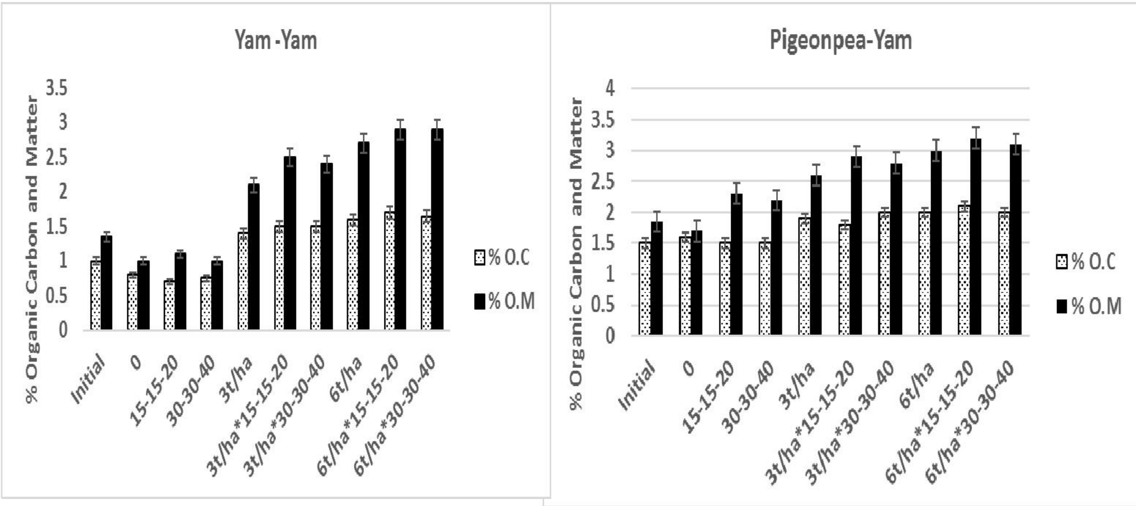

Figure 3 : Soil carbon and organic matter at planting (Initial) and at harvest as influemced by Preceding system, poultry manure and chemical fertilizer at Ejura, Ghana.

Carbone du sol et matière organique au moment des semis (Initiale) et lors de la récolte sont influencés par le système précédent, fumier de volaille et engrais chimique à Ejura, Ghana.

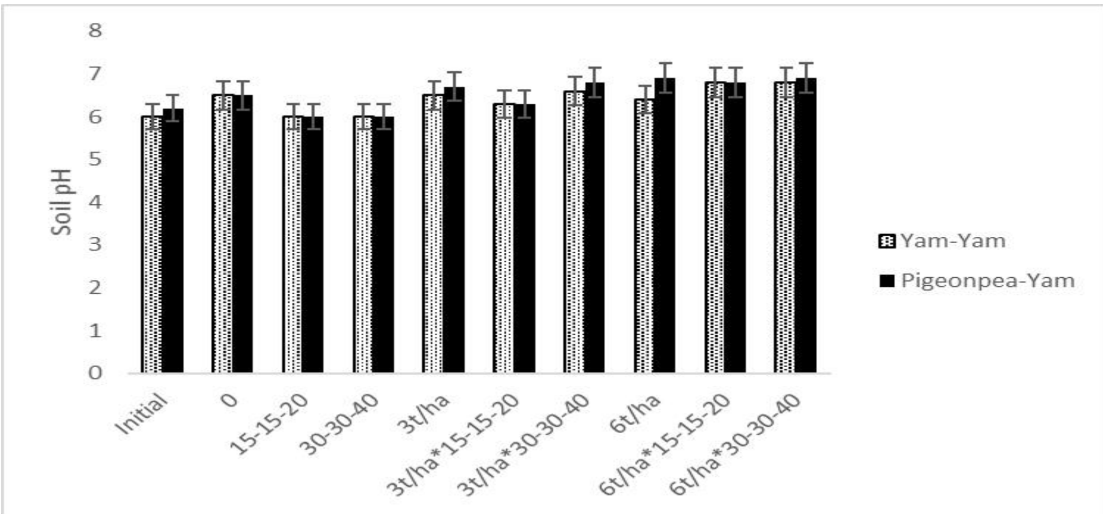

Figure 4 : Soil pH at planting (Initial) and at harvest as influemced by Preceding system, poultry manure and chemical fertilizer at Ejura, Ghana.

PH du sol au moment des semis (Initiale) et à la récolte est influencé par le système précédent, fumier de volaille et engrais chimiques à Ejura, Ghana.

Table 2 : Partial budget and cost benefit analysis of integrated soil nutrient management options at Fumesua.

Analyse du budget partiel et des coûts-bénéfices des options de gestion intégrée des nutriments du sol à Fumesua

Proceding system	Yam-Yam								
Poultry Manure	Ot/ha			3t/ha			6t/ha		
Chemical Fertilizer	O-O-O N- P_2O_5- K_2O Kg/ha	15-15-20 N-P_2O_5- N-P_2O_5- K_2O Kg/ha	30-30-40 P_2O_5- K_2O Kg/ha	O-O-O N- N-P_2O_5- N-p_2O_5- K_2O Kg/ha	15-15-20 P_2O_5- K_2O Kg/ha	30-30-40 N-P_2O_5- N-P_2O_5- K_2O Kg/ha	O-O-O N K_2O Kg/ha	15-15-20 K_2O Kg/ha	30-30-40 K_2O Kg/ha
Averge yields (kg/ha)	4800	6500	7450	6750	8460	8050	7140	9150	9700
Adjusted yield*	4320	5931	6705	6075	7614	7245	6426	8235	8730
Gross benefit (₵ /ha)	3.024	4.152	4.694	4.253	5.330	5.072	4.498	5.765	6.111
Cost of poultry manure (₵ /ha)	0	0	0	80	80	80	160	160	160
Labour cost poultry manure appl. (₵ /ha)	0	0	0	50	50	50	100	100	100
Cost of chemical fertilizer (₵)	0	90	180	0	90	180	0	90	180
Labour cost of application of Fert. (₵ /ha)	0	50	100	0	50	100	0	50	100
Cost of land clearing & stomping (₵ /ha)	110	110	110	110	110	110	110	110	110
Construction of ridges (₵ /ha)	70	70	70	70	70	70	70	70	70
Cost of seed yam (₵)	1125	1125	1125	1125	1125	1125	1125	1125	1125
Labour cost of planting (₵ /ha)	50	50	50	50	50	50	50	50	50
Cost of stakes (₵ /ha)	65	65	65	65	65	65	65	65	65
Labour cost of staking (₵ /ha)	45	45	45	45	45	45	45	45	45
Cost of weeding and reshaping (₵ /ha)	100	100	100	100	100	100	100	100	100
Harvesting cost (₵ /ha)	30	30	30	30	30	30	30	30	30
Total cost that vary	1.595	1.735	1.875	1.725	1.865	2.005	1.855	1.995	2.135
Net benefit	1.429	2.417	2.819	2.528	3.465	3.067	2.643	3.770	3.976
Benefit cost/Ratio	0.90	1.39	1.5	1.47	1.86	1.53	1.42	1.89	1.86

Table 2 following

Proceding system	Pigeongea-Yam								
Poultry Manure	Ot/ha			3t/ha			6t/ha		
Chemical Fertilizer	O-O-O N-P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-P_2O_5-K_2O Kg/ha	O-O-O N-P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-p_2O_5-K_2O Kg/ha	O-O-O N P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-P_2O_5-K_2O Kg/ha
Averge yields (kg/ha)	6790	8600	7900	7800	10800	10200	8900	11100	10000
Adjusted yield*	6111	7740	7110	7020	9720	9180	8010	9990	9000
Gross benefit (₵ /ha)	4.278	5.418	4.977	4.914	6.804	6.426	5.607	6.993	6.300
Cost of poultry manure (₵ /ha)	0	0	0	80	80	80	160	160	160
Labour cost poultry manure appl. (₵/ha)	0	0	0	50	50	50	100	100	100
Cost of chemical fertilizer (₵)	0	90	180	0	90	180	0	90	180
Labour cost of application of Fert. (₵ /ha)	0	50	100	0	50	100	0	50	100
Cost of land clearing & stomping (₵/ha)	110	110	110	110	110	110	110	110	110
Construction of ridges (₵ /ha)	70	70	70	70	70	70	70	70	70
Cost of seed yam (₵)	1125	1125	1125	1125	1125	1125	1125	1125	1125
Labour cost of planting (₵/ha)	50	50	50	50	50	50	50	50	50
Cost of stakes (₵ /ha)	65	65	65	65	65	65	65	65	65
Labour cost of staking (₵ /ha)	45	45	45	45	45	45	45	45	45
Cost of weeding and reshaping (₵ /ha)	100	100	100	100	100	100	100	100	100
Harvesting cost (₵ /ha)	30	30	30	30	30	30	30	30	30
Total cost that vary	1.595	1.735	1.875	1.725	1.865	2.005	1.855	1.995	2.135
Net benefit	2.683	3.683	3.102	3.189	4.939	4.421	3.752	4.998	4.165
Benefit cost/Ratio	1.68	2.12	1.65	1.85	2.65	2.20	2.02	2.51	1.95

NB:* Average yield adjusted 10 %; Gh ₵ Farm gate price per kg of Dente in 2012 = Gh ₵ 0.70

Table 3 : Partial budget and cost benefit analysis of integrated soil nutrient management options at Ejura.

Analyse du budget partiel et des coûts-bénéfices des options de gestion intégrée des nutriments du sol à Ejura

Proceding system	Yam-Yam								
Poultry Manure	Ot/ha			3t/ha			6t/ha		
Chemical Fertilizer	O-O-O N-P_2O_{5}-K_2O Kg/ha	15-15-20 N-P_2O_{5}-K_2O Kg/ha	30-30-40 N-P_2O_{5}-K_2O Kg/ha	O-O-O N-P_2O_{5}-K_2O Kg/ha	15-15-20 N-P_2O_{5}-K_2O Kg/ha	30-30-40 N-p_2O_{5}-K_2O Kg/ha	O-O-O N P_2O_{5}-K_2O Kg/ha	15-15-20 N-P_2O_{5}-K_2O Kg/ha	30-30-40 N-P_2O_{5}-K_2O Kg/ha
Averge yields (kg/ha)	4850	6460	7110	6790	8140	7890	6530	7640	8030
Adjusted yield*	4365	5814	6399	6111	7326	7101	5877	6876	7227
Gross benefit (₵/ha)	3.056	4.070	4.479	4.278	5.128	4.971	4.114	4.813	5.059
Cost of poultry manure (₵/ha)	0	0	0	80	80	80	160	160	160
Labour cost poultry manure appl. (₵/ha)	0	0	0	50	50	50	100	100	100
Cost of chemical fertilizer (₵)	0	90	180	0	90	180	0	90	180
Labour cost of application of Fert. (₵ /ha)	0	50	100	0	50	100	0	50	100
Cost of land clearing & stomping (₵/ha)	110	110	110	110	110	110	110	110	110
Construction of ridges (₵/ha)	70	70	70	70	70	70	70	70	70
Cost of seed yam (₵)	1125	1125	1125	1125	1125	1125	1125	1125	1125
Labour cost of planting (₵/ha)	50	50	50	50	50	50	50	50	50
Cost of stakes (₵ /ha)	65	65	65	65	65	65	65	65	65
Labour cost of staking (₵ /ha)	45	45	45	45	45	45	45	45	45
Cost of weeding and reshaping (₵/ha)	100	100	100	100	100	100	100	100	100
Harvesting cost (₵ /ha)	30	30	30	30	30	30	30	30	30
Total cost that vary	1.595	1.735	1.875	1.725	1.865	2.005	1.855	1.995	2.135
Net benefit	1.461	2.335	2.604	2.553	3.263	2.966	2.259	2.818	2.924
Benefit cost/Ratio	0.92	1.35	1.39	1.48	1.75	1.48	1.22	1.41	1.37

Table 3 following

Proceding system	Pigeonpea-Yam								
Poultry Manure	Ot/ha			3t/ha			6t/ha		
Chemical Fertilizer	O-O-O N-P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-P_2O_5-K_2O Kg/ha	O-O-O N-P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-p_2O_5-K_2O Kg/ha	O-O-O N P_2O_5-K_2O Kg/ha	15-15-20 N-P_2O_5-K_2O Kg/ha	30-30-40 N-P_2O_5-K_2O Kg/ha
Averge yields (kg/ha)	7680	11250	10490	9070	12500	11790	8900	11800	11100
Adjusted yield*	6912	10125	9441	8163	11250	10611	8010	10620	9990
Gross benefit (₵/ha)	4.838	7.088	6.609	5.714	7.875	7.428	5.607	7.434	6.993
Cost of poultry manure (₵/ha)	0	0	0	80	80	80	160	160	160
Labour cost poultry manure appl. (₵/ha)	0	0	0	50	50	50	100	100	100
Cost of chemical fertilizer (₵)	0	90	180	0	90	180	0	90	180
Labour cost of application of Fert. (₵/ha)	0	50	100	0	50	100	0	50	100
Cost of land clearing & stomping (₵/ha)	110	110	110	110	110	110	110	110	110
Construction of ridges (₵/ha)	70	70	70	70	70	70	70	70	70
Cost of seed yam (₵)	1125	1125	1125	1125	1125	1125	1125	1125	1125
Labour cost of planting (₵/ha)	50	50	50	50	50	50	50	50	50
Cost of stakes (₵/ha)	65	65	65	65	65	65	65	65	65
Labour cost of staking (₵/ha)	45	45	45	45	45	45	45	45	45
Cost of weeding and reshaping (₵/ha)	100	100	100	100	100	100	100	100	100
Harvesting cost (₵/ha)	30	30	30	30	30	30	30	30	30
Total cost that vary	1.595	1.735	1.875	1.725	1.865	2.005	1.855	1.995	2.135
Net benefit	3.243	5.353	4.734	3.989	6.010	5.423	3.752	5.439	4.858
Benefit cost/Ratio	2.03	3.09	2.52	2.31	3.22	2.70	2.02	2.73	2.28

NB:* Average yield adjusted 10% ; Gh₵ Farm gate price per kg of Dente in 2012 = Gh₵ 0.70

DISCUSSION

The insignificant differences in the number of sprout days after planting and at harvest according for the locations and the preceding systems, suggesting that application of the treatments such as poultry manure did not influence the sprouting rate of the seed yam. This might be partially attributed to the chemical treatments of the seed yam planting material before planting. Eze and Orkwor (2010) attributed differences in sprout rates to differences in yam variety and part of the tuber used than organic manure and mineral fertilizer applied to the soil. Therefore, the use of manure and mineral fertilizer in yam production seems to have no significant effect on the sprouting. Generally, the total yields on the fields preceded by pigeon pea were higher as compared to the fields preceded by yam (Figure 2a, 2b, 2c and 2d). This might be due to the residual nitrogen effect from the pigeon pea through biological nitrogen fixation. The generally low yields of yam irrespective of the preceding system at Fumesua as compared to Ejura may be due to the total rainfall and the differences in the soils at Fumesua and Ejura (Table 1). Ennin *et al*. (2009) made a similar observation in a cassava study, that the well-drained sandy loam Lixisols in Ejura favoured development of bigger sized cassava roots leading to higher cassava yields than on the shallow sandy clay loam Acrosols at Fumesua.

A study by Ennin *et al*. (2014), recommended 45 - 45 - 60 kg ha^{-1} N-P_2O_5-K_2O for sustainable yam prodcution on contineously cropped fields. However, It can be observed from Figures 2a and 2c that on continuously cropped fields, application of poultry manure at 3 t ha^{-1} and 15 - 15 - 20 N P_2O_5 K_2O kg ha^{-1} did significantly ($P \leq 0.05$) increase the yield as compared to fields where no fertilizer or poultry manure applied. However, doubling the poultry manure and chemical fertilizer rate from 3 t ha^{-1} and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} to 6 t ha^{-1} and 30 - 30 - 60 N-P_2O_5-K_2O kg ha^{-1} respectively, did not make significant ($P > 0.05$) differences in soil organic matter content and yam tuber yield (Figure 2a, 2b and 3). When a third of the recommended chemical fertilizer (15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1}) was applied on continuously cropped fields, the benefit ratios were 1.39 and 1.35 for Fumesua and Ejura respectively. Integration with 3 t ha^{-1} and 6 t ha^{-1} poultry manure increased the benefit cost ratio to 1.86 ; 1.75 and 1.89 ; 1.41 for Fumesua and Ejura respectively (Table 2 and 3). This suggest, it would be unprofitable to double the poultry manure and mineral fertilizer rate from 3 t ha^{-1} to 6 t ha^{-1} and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} to 30 - 30 - 60 N-P_2O_5-K_2O kg ha^{-1}. Thus, the study suggests on continuously cropped fields with the integrated soil nutrient approach with poultry manure a third (15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1}) of the recommended (45 - 45 - 60 N-P_2O_5-K_2O kg ha^{-1}) would be needed.

The yields on the fields preceded by pigeon pea followed similar trends as on the continuously cropped fields. The yields of fields treated with poultry manure at 3 t ha^{-1} and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} and the double rate (2b and 2d) were similar. Also, a benefit cost ratio of 2.65 and 3.22 were observed on fields preceded with pigeon pea, 3 t ha^{-1} poultry manure and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} in Fumesua and Ejura respectively (Table 2 and 3). This indicates that a Gh₵1.00 invested capital with an integrated soil nutrient management of 3 t ha^{-1} poultry manure and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} preceded by pigeon pea would accrue a profit of Gh₵ 1.65 and Gh₵ 2.22 in addition to the Gh₵1.00 invested capital in Fumesua and Ejura respectively (Table 2 and 3). Whiles on continuously cropped fields with an integrated soil nutrient management of 3 t ha^{-1} poultry manure and 15-15-20 N-P_2O_5-K_2O kg ha^{-1} accrued a profit of Gh₵ 0.86 and Gh₵ 0.75 in addition to the invested Gh₵1.00 (Table 2 and 3).

It can be observed that the preceded system made differences in the total tuber yield and profit margins of yam production in both locations (Fig. 2a, 2b, 2c and 2d ; Table 2 and 3). Thus at least preceding system with legume without fertilizer or manure could sustain yam production to some extent. Figures from the Food and Agriculture Organization indicated that yam production in Ghana increased over 30.8 % between 2008 and 2013 with a corresponding increase in area of cultivation of about 18 % in the same period (FAOSTAT, 2015). This suggests that, a percentage increase in area under yam cultivation would lead to a corresponding increase in yam production of about 1.7 %. However, with the increased pressure on cropping land as a result of population increase and the concomitant shortening of fallow periods, food security cannot be supported with this trend (Quansah *et al.*, 2001 ; Garrity, 2004 ; PPMED, 2007).

The use of legumes such as cowpea, soya beans, groundnuts etc. in sustaining yields of cereals such as maize, millet, sorghum etc is well known (Asafu-Agyei *et al*., 1997 ; Kombiok *et al*., 1997 ; Ennin *et al*., 2004). With the recognition that yam is root and tuber and therefore heavy soil nutrient feeder (Ferguson and Haynes, 1970 ; Le Buanec, 1972) as compared to the cereals implies the addition of manure and or chemical fertilizer. This study suggests integrated soil nutrient approach of legume preceding system with 3 t ha^{-1} manure and 15 - 15 - 20 N-P_2O_5-K_2O kg ha^{-1} chemical fertilizer for sustainable yam production. The integrated soil nutrient management approach would promote better soil and environmental health in sustaining yam production on continuously cropped fields to reduce the pressure on virgin lands to address the problem of deforestation.

CONCLUSION

Integrated soil nutrient approach with poultry manure and mineral fertilizer at a rate of 3 t ha^{-1} and 15 - 15 - 20 N P_2O_5 K_2O kg ha^{-1} proceeded by pigeon pea can be used in sustaining yam yields on continuously cropped fields. It is expected that, other legumes such as Cowpea, Groundnut, Bambara groundnut etc. would give similar results. This would need verification at the field. It is recommended that, farmers are encourage to use manure and chemical fertilizer and legumes preceding system in yam production as its being used in the production of cereals. The use of integrated soil nutrient approach would reduce the chemical fertilizer requirement to a third for sustainable yam production. This would greatly reduce the contribution of yam production to deforestation and climate change to ensure food security and environmental protection.

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REFERENCES

Akwaag A.A., Berchie J.N., Echavez M.L., Dapaah H.K., Kebede T., Njue S.W., Paraoam I., Labrada H.R. 2000. Sustainable Farming Practices- Towards Reducing the Expansion of the Forest Savanna Trasitional Zone of the Sekyere-West and Ejura-Sekyeredumase Districts of the Ashanti Region of Ghana. International Center for Development Oriented Research in Agriculture and crops Research Institute, Working Document Series 86, Ghana

Adu S.V., Asiamah R.D. 1992. Soils of the Ayensu-Densu Basin, Central, Eastern and Greater Accra Regions of Ghana. Council for Scientific and Industrial Research (CSIR) – Soil Research Institute Memoir 9, 117 p

Asante A.K. 1996. Use of bast fibre plants as staking materials for yam production in the Guinea Savanna zones of Ghana. Ghana Journal of Agricultural Science. National Science of and Technology Press 28 - 29 : 99 - 103.

Asafu-Agyei J.N., Ahenkora K., Banful B., Ennin-Kwabiah S. 1997. Sustaining Food Production in Ghana: the Role of Cereal/Legume Based Cropping Systems. *In* : Bezuneh T. Emechebe A.M Sedge J., Ouedrago M. (eds.). 1997. Technology options for sustainable agriculture in Sub-Saharan Africa. Publication of the Semi-Arid Food Grain Research and Development Agency (SAFGRAD) of the scientific, technical and research commission of OAU, Ouagadougou, Burkina Faso, pp 409 - 416.

Diby L.N., Sangakkara R., Tie B.T., Girardin O., Frossard E. 2011. Growth and Nutrient Use Efûciencies of Yams (*Dioscorea spp.*) Grown in Two Contrasting Soils of West Africa. Hindawi Publishing Corporation International Journal of Agronomy Volume 2011, Article ID 175958, 8 pages doi : 10.1155/2011/175958

Ennin S.A., Otoo E., Tetteh F.M. 2009. Ridging, a Mechanized Alternative to Mounding for Yam and Cassava Production. West African Journal of Applied Ecology 15 : 1 - 8.

Ennin S.A., Otoo E., Isaaka R.N., Acheampong P.P., Numafo M., Owusu Danquah E. 2014. Mechanization, Fertilization and Staking Options for Environmentally Sound Yam Production. African Journal of Agricultural Research 9 (29) : 2222 - 2230.

Ennin S.A., Dapaah H.K., Abaidoo R.C. 2004. Nitrogen Credits from Cowpea, Soybean, Groundnut and Mucuna to Maize in Rotation. West Africa Journal of Applied Ecology 6 : 65 - 74

Eze S.C., Orkwor G.C. 2010. Studies on effects of mineral fertilizer, organic manure and cultivar on the yield and storability of Yam (*Dioscorea rotundata* Poir). African Journal of Food Agriculture, Nutrition and Development 10 (6) : 2755 - 2771

FAOSTAT 2015. Food Production Statistics. FAO Statistics Division 2015. http://www.fao.org/faostat/en/#data

FAOSTAT 2006. Food Production Statistics. FAO Statistics Division 2006. http://www.fao.org/faostat/en/#data

Ferguson T.U., Haynes P.H. 1970. The response of yams (*Dioscorea spp.*) to nitrogen, phosphorus, potassium and organic fertilizers. Tropical Root and Tuber Crops Tomorrow: Proceedings of the 2nd International Symposium on Tropical Root and Tuber Crops (Hawaii, 1970) (Plucknett D.L., ed.), Vol. I, pp. 93 - 96. Honolulu, Hawaii: College of Tropical Agriculture, University of Hawaii.

Garrity D. P. 2004. Agroforestry and the Achievement of the Millennium Development Goals. *In* : Nair P.K., Rao M.R., Buck L.E. (eds). New Vistas in Agroforestry, Kluwer Academic Publishers, Netherland.

Kombiok J.M., Dogbe W., Kanton R. 1997. Cropping Systems and Long-Term Soil Fertility Management for Sustainable Agriculture in Northern Ghana. *In* : Bezuneh T., Emechebe A.M., Sedge J., Ouedrago M. (eds.). Technology options for sustainable agriculture in Sub-Saharan Africa. Publication of the Semi-Arid Food Grain Research and Development Agency (SAFGRAD) of the scientific, technical and reseaerch commission of OAU, Ouagadougou, Burkina Faso, pp 417 - 424.

Le Buanec B. 1972. Absorption and uptake of major nutrients by yams. GERDAT.Groupement d'Etudes et de Rechèrche pour le Dévelopment de l'Agronomie Tropicale. IRAT. Institut de Rechèrches Agronomiques Tropicales et des Cultures Vivrières. Nogent-sur-Marne (Côte d'Ivoire). Réunion d'Agronomie de l'IRAT : 1974/07/04 - 12 ; Paris (FRA) Bouaké (CIV) : GERDAT-IRAT.

Otoo E., Anchirina V.M., Ennin S.A., Asiedu R. 2008. Sustainable yam production in Ghana the non-staking option. Journal of Food Agriculture & Environment 6 (3&4) : 391 - 396

Quansah C., Drechsel P., Yirenkyi B.B., Asante-Mensah S. 2001. Farmers' perception and management of soil organic matter-a case study from West Africa. Nutrient Cycling in Agroforestry Systems 61 : 205 - 213.

PPMED 2007. Agriculture in Ghana-Facts and Figures. Policy Planning, monitoring and Evaluation. Ministry of Food and Agriculture, Ghana

Young A. 1997. Agroforestry for Soil Management. 2nd edition. CAB International & International Centre for Research in Agroforestry, Wallingford/Nairobi.