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Yam Plant Growth and Tuber Yield Response to Ex-Situ Mulches of Moringa Oleifera, Chromolaena Odorata and Panicum Maximum Under Three Natural Fallow Aged Systems

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ABSTRACT

A field study was conducted at Atonsu, Sekyere Central District of the Ashanti region in Ghana from 2013 to 2014, to(i) determine the effects of ex-situ mulches of Moringa oleifera, Chromolaena odorata and Panicum maximum on yam tuber yield under three natural fallow aged systems and (ii) assess the changes in the physico- chemical properties of the soil with the application of the ex-situ mulches. The field experiment was laid out in a 3x3 factorial arrangement in a Randomized Complete Block Design (RCBD) with three replications. The first factor was ex-situ mulch types at three levels; Panicum maximum (farmers'choice), Chromolaena odorata and Moringa oleifera. The second factor was natural fallow aged systems at three levels; 3-year old, 5-year old and 7- year old. Data collected included changes in soil physico-chemical properties, residue decomposition and nutrient release patterns, yam growth parameters and total tuber yield of yam. After two years of mulch application and cropping, there were significant increases in soil pH, nitrogen, organic matter, calcium and E.C.E.C levels for all the three mulches in comparison to their initial contents. In spite of this, soils under Moringaoleifera mulch recorded significantly higher contents of total nitrogen and organic matter than under the Panicum maximum and Chromolaena odorata mulches Furthermore, M. oleifera produced significantly the highest tuber yields. In terms of yield sustainability over the two years cropping period, there was less yield decline arising from the application of the M. oleifera mulch (19.17%) than from C. odorata (31.53%) and P. maximum (48.20%) mulch applications. The study concluded that M. oleifera mulch was better able to improve and sustain soil fertility which subsequently resulted in higher yam tuber yields than the other mulches of C. odorata and P. maximum. Furthermore, yield reductions in yam was least under M. oleifera mulch and therefore could be considered as the best candidate to ensure sustainable yields of yam on the same piece of land for longer cropping periods.

Keywords: *Soil physico-chemical properties, yam growth, soil nutrients, tuber yield;*

INTRODUCTION

Traditionally in Ghana, yam is the first crop to be cultivated after clearing a virgin forest or on lands with long fallow periods (> 15 years) since such lands result in good yields. [1]. Unfortunately, just after one or two years of continuous cropping, there is a drastic and significant decline in yam yields, a situation principally attributed to a tremendous decline in soil fertility [2]. This is because, yam is a heavy feeder which takes up a lot of nutrients from the soil. On the average, nutrient up take from soil perton of fresh yamis N-2.7t/ha; P-0.5t/ha; K-3.2t/ha; Ca-0.2 t/ha and Mg-0.4t/ha[3].

This depleted situation is further exacerbated by the pressureonland due to human population increase. As a result, land availability becomes very limited which forces farmers to continuously crop on the same piece of land for several years, without rejuvenation of the lost fertility through fallowing of the land, leading to persistent low yam yields [4, 5]

Mulching is a major aspect of yam (Dioscorea spp.) production since it aids in the manipulation of the crop environment to ensure the conservation of soil moisture, reduction of soil temperature and enhancement of soil organic matter with an ultimate reflection in increased yam yields [6-11]. To reverse the continuous decline in soil fertility on croppedland therefore, innovative systems with positive effects on soil fertility sustenance would need to be developed for yam-based cropping systems. In this direction, the most viable alternative system is the use of ex-situ high quality mulches to several crops have resulted in yield increases of these crops through an improved and sustained soil fertility mechanism [12].

Currently, the two preferred high quality mulches are *Moringa oleifera* and *Chromolaena odorata* [11,13]. These mulches, through decomposition, have caused the increase in the size and water stability of soil aggregates, reduction in the soil bulk density [14], improvement in the content of soil organic carbon and an increase in the availability of soil nutrients [15]. These good effects of the high quality mulches have however been proven only on cereals and vegetables but not on root and tuber crops. As such thereisadearth of information on the potential of *M. oleifera* and *C. odorata* as high quality mulches in root and tuber crops production, including yam. The objectives of the study therefore were to;

- Assess the changes in the physico-chemical properties of soil under three natural fallow aged systems with the application of ex-situ mulches of *Moringa oleifera*, *Chromolaena odorata* and *Panicum maximum* (Farmers'choice).
- Determine the effects of the ex-situ mulches application on the growth and tuber yield of yam under the three fallow aged systems.

MATERIALS AND METHODS

Experimental Locations, Design and Procedure

The field experiment was carried out at Atonsu village which had a good representation of all the three natural fallow ages viz: three-year old (3-year), five years (5-year) and seven years (7-year) that would be used. The 3-year and 5-year old natural fallows were previously cropped to cowpea and cassava, respectively, whiles the7-year old natural fallow was previously cropped to cocoyam.

The experimental design was a 3 x 3 factorial arrangement in randomized complete block with three replications. The first factor was natural fallow age at three levels, namely, 3-year, 5-year and 7-year. The second factor was mulch type at three levels comprising, Chromolaena odorata mulch, Moringaoleifera mulch and Panicummaximum mulch (control-farmer practice).

The plot size within each natural fallow age system was 5 m x 4 m with an experimental area of 2,000 m2 (50 m x 40m). Preparation of ridges, plots demarcation and all other cultural practices were done in accordance with the methodology of Ennin et al., [16]. The inter-ridge spacing was 1 m whiles the inter-plot spacing was 3 m. Yam (Dioscorea rotundata var. Puna) setts with uniform size and a mean weight of 250g were plant edon the ridges at a spacing of 1m x 0.5m. There were 36 plants per plot (18,000plantsha- 1).

Two croppings were done over the study period, namely, in 2013 and in2014.All three mulch types were applied at a rate of 0.5 kg plant-1 (10 t ha-1) in both years of cropping. There were two split applications of each mulch type during each cropping period. The first half, applied at a rate of 0.25 kg plant-1 (5t ha-1) was done 28 days after planting of yam whiles the second half was done 75 days after planting [11].

Data collected included rainfall, temperature, soil nutrient content, nutrient content of mulches, percent am sett establishment, yam vine length, yam number of leaves, yam number of branches, yam leaf area, yam tuber yield, tuber physical quality.

Data Analysis

Data obtained from the two experiments were subjected to analysis of variance using Genstatversion10.Treatmentmeanswereseparatedusing Tukeys Honestly Significant Difference (HSD) at 5% level of probability.

RESULTS

Climatic Conditions during the Experimental Period

Maximum Environmental temperatures during the two year experimental period ranged between 28.0^{O}C and 33.0 ^{O}C (Table 1). Rainfall during the two cropping seasons ranged between 28.8 and 290.4 mm. The lowest rainfall amounts occurred in August in 2013 and in November in 2014 (Table1). Total annual rainfall amounts from start of cropping to harvest for 2013 and 2014 were 942.9 and 1293.0 cm, respectively.

Table1. *Monthly rainfall and temperature recorded during the growing season of yam between 2013 and 2014.*

Year	April	May	June	July	August	September	October	November	Total
Rainfall (mm)									
2013	121.3	204.0	64.3	54.8	28.8	252.6	149.9	67.2	942.9
2014	290.4	232.3	196.3	94.2	114.7	120.6	213.1	31.4	1293.0
			Maximum Temperature(^{O}C)						
2013	32.0	32.0	29.5	28.9	28.3	29.9	31.0	31.5	
2014	33.0	32.0	30.0	28.5	28.0	30.0	30.5	31.5	

Source: *Ghana Meteorological Agency (2015)*

Initial Soil Physico-Chemical Properties of Three Natural Fallow Aged Systems

Table 2 shows the initial soil physical and chemical properties of the three fallow aged systems at 0 - 20 cm soil depth. There were significant differences between the fallow aged systems for only organic matter within the 0-20cm depth. The 7-year fallow contained significantly higher levels of organic matter than the 3–year fallow, although similar to that of the 5-year fallow. Generally, the soils were acidic, moderate in organic matter (OM) and available potassium (K) but low in nitrogen (N), available phosphorus (P), Effective cation exchange capacity (ECEC) and exchangeable calcium (Ca). The 3-year and the 7-year fallows were sandy loam whereas the 5-year fallow was sandy clayloam.

Table2. *Initial soil physical and chemical properties of the three fallow ages at 0 - 20 cm soil depth*

Fallow age	pH (H2O)	Total N (%)	Organic matter (%)	Available P (mg kg^{-1})	Available K(mg kg^{-1})	Exch Ca (cmol kg^{-1})	Exch Mg (cmol kg^{-1})	E.C.E.C	BD	% Sand	% Silt	% Clay
3yr	5.68a	0.08a	1.49b	6.91a	72.54a	3.03a	2.05a	5.78a	1.42a	74.92a	23.08a	2.00a
5yr	5.46a	0.09a	1.84ab	3.00a	74.77a	3.91	1.78a	6.59a	1.31a	68.17a	28.50a	3.33a
7yr	5.39a	0.11a	2.22a	2.72a	70.53a	5.07a	2.14a	8.20a	1.38a	75.52a	22.48a	2.00a
HSD	1.81	0.05	0.47	7.15	22.27	2.47	1.75	4.25	0.74	11.2	10.55	1.51

Means with the same subscript within a column do not differ significantly (p>0.05)

Nutrient Content of Leaves of the Three Mulches

Table 3 shows the results of chemical analysis and resource quality characteristics of the freshP. *maximum*, *M.oleifera*, and *C.odorata* leaves and stem residues. Among the three mulch materials,*M. oleifera* leaf residues contained significantly ($p<0.05$) higher concentrations of nitrogen, phosphorus, potassium, calcium and magnesium than *C. odorata* and *P. maximum*. *C.odorata* leaves also had significantly higher contents of all the nutrients studied than *P. maximum*. The nutrient composition of the leaf residues were therefore found to be in the order:

M. oleifera > *C. odorata* > *P. maximum*. The C/N ratios of the leaf residues of *C. odorata*, *M. oleifera and P. maximum* were 18.73, 8.38 and 43.12, respectively whiles the half-lives of the leaf residues consequently ranged from 2.8 - 4.8weeks.

Table3. *Nutrient content, C/N ratio and decomposition half-life values of mulch materials used in the study*

Mulch type	%N	%P	%K	%Ca	%Mg	C/N	half-life (week^{-1})
P. maximum	0.90c	0.13c	2.00c	0.29c	0.26c	43.12	4.8
C. odorata	1.60b	0.24b	2.52b	0.44b	0.50b	18.73	4.0
M. oleifera	3.87a	0.29a	2.88a	0.50a	0.59a	8.38	2.8
HSD (0.05)	0.039	0.023	0.138	0.054	0.068		

Means with the same subscript within a column do not differ significantly (p>0.05)

Soil Physico-Chemical Properties under the Three Mulches after Two Years of Mulch Application and Yam Cropping

There were no significant fallow age x mulch type interactions for all the parameters measured after two years of mulch application and cropping at both 0-20cm and 20-40cm depth. Similarly, among the mulch types at 0-20cm soil depth, there were no significant differences for all the parameters measured. Soil pH ranged between 5.66 and 5.80; total nitrogen was between 0.1% and 0.11%; organic matter was between 2.07% and 2.28%; calciumwas between4.63 and 4.91cmolkg^{-1} and magnesium was between 1.69cmolkg^{-1} and 1.90cmolkg^{-1}.For bulk density, the ranges for the mulch types were *P. maximum* - 1.22-1.30; *C. odorata* - 1.18-1.29 and *M. oleifera* - 1.19-1.29. At 20 - 40 cm depth however, there were significant differences between the mulch types for total nitrogen, organic matter and exchangeable calcium (Table4).

For both total nitrogen and organic matter, soil under *Moringaoleifera* mulch had significantly higher contents than under *C.odorata*, although not different from those under *P.maximum*. On the other hand, soil under *P. maximum*, had the highest content of calcium, significantly greater than those under *C. odorata* and *M.oleifera*.

Table4. *Soil physical and chemical properties (20 to 40 cm depth) under the different mulch types after two years of cropping*

	pH (H2O)	Total N (%)	Organic matter (%)	Av. P (mgkg^{1})	Av. K (mgkg^{-1})	Exch. Ca (cmolkg^{-1})	Exch.Mg (cmol kg^{-1})	BD	% sand	% silt	% Clay
P.maximum	5.73a	0.12ab	2.35ab	5.16a	52.69a	5.37a	1.85a	1.25a	70.69a	24.24a	5.07a
C. odorata	5.79a	0.10b	2.01b	3.69a	56.44a	4.24b	1.99a	1.24a	70.2a	24.60a	5.2a
M. oleifera	5.85a	0.13a	2.71a	5.20a	42.35a	4.94ab	1.57a	1.23a	70.66a	24.27a	5.07a
HSD	0.24	0.03	0.63	1.57	27.66	1.06	0.19	0.02	4.54	3.94	1.3

Means with the same subscript within a column do not differ significantly (p>0.05)

Effects Mulching on Growth, Tuber Yield and Tuber Physical Quality of Yam in Three Fallow Aged Systems Growth Parameters of Yam

There was no significant fallow aged system x mulch type interactions for any of the growth parameters for the two years of cropping. For the first year of yam cropping, there were also no significant differences between the mulches for all the yam growth parameters measured. For the second year of yam cropping however, significant differences were found between the mulches for vine length, number of leaves, and number of branches (Table 5). Yam vine length was significantly longer under *M.oleifera* mulch although not different from that under *P. maximum*mulch.

The shortest yam vines were produced under *C. odorata* mulch. Similarly, the number of leaves was greater in yam to which *M. oleifera* had been applied although not different to that to which *P. maximum* had been applied. The least number of leaves was produced by yam to which *C. odorata* mulch had been applied. Furthermore yam to which *M. oleifera* had been applied produced the highest number of branches, significantly greater than that under *P. maximum* mulch which produced the least. There were however no significant differences between the mulch types for percent sett establishment and leaf area index.

In terms of the fallow aged systems, significant differences were observed for percent sett establishment, number of leaves and leaf area index (Table6).The percent sett establishment was highest under the 7-year fallow system, although not different from that of the 3-year fallow system. The least sett establishment was found under the 5-year fallow system. The number of leaves and leaf area index of yam followed a similar trend such that the 7-year fallow system produced the highest leaf numbers and biggest leaf area index as compared to the 5-year and 3-year fallow systems. For vine length and number of branches, no differences were found between the fallow aged systems. For the second cropping however, vine length and number of leaves were found to show significant differences between the fallow aged systems(Table7).

Table5. *Effects of mulch types on vine length, number of leaves and number of branches of yam during second year cropping*

Mulch type	Vine Length (cm)	Number of leaves	Number of branches
P. maximum	151.3ab	229.4ab	18.6b
C. odorata	133.6b	218.1b	22.0ab
M. oleifera	171.9a	279.9a	23.7a
HSD (0.05)	35.92	51.51	3.73

Means with the same subscript within a column do not differ significantly (p>0.05)

Table6. *Effects of fallow ages on percent sett establishment, number of leaves and leaf area index of yam for the first year yam cropping*

Fallow aged System	Number of leaves	% sett establishment (6WAP)	Leaf Area Index (21WAP)
3-year	260.1b	75.0a	3.5b
5-year	202.2b	65.7b	2.5b
7-year	373.5a	80.2a	6.0a
HSD (0.05)	88.72	8.49	1.60

Means with the same subscript within a column do not differ significantly (p>0.05)

Table7. *Effects of fallow ages on vine length and number of branches of yam for the second year cropping*

Fallow age system	Vine Length (cm)	Number of branches
3-year	150.8ab	25.2a
5-year	182.9a	16.0b
7-year	123.1b	23.0a
HSD (0.05)	35.49	3.72

Means with the same subscript within a column do not differ significantly (p>0.05)

Changes in Tuber Yield Under the Mulch Types and within the Fallow Aged Systems

Yield Sustenance over Two Years of Cropping under the Mulches

Yam to which *M. oleifera* was applied significantly produced the highest yield which was consistent over the two years of cropping (Table8).The least yam yields were produced under the *P. maximum* mulch. Over the two years, although yield reductions occurred, the least reduction (less than 20%) was found in yam to which *M. oleifera* was applied. The greatest yield reduction (almost 50%) was found in yam to which *P. maximum* was applied.

Table8. *Percent tuber yield reductions under the three ex-situ mulch types*

Tuber yield	*P. maximum* (t/ha)	*C. odorata* (t/ha)	*M. oleifera* (t/ha)	HSD (0.05)
First cropping tuber yield	30.5b	33.3ab	41.2a	10.48
Second Cropping tuber yield	15.8c	22.8b	33.3a	6.62
Yield reduction (%)	48.20	31.53	19.17	

Means with the same subscript within a column do not differ significantly (p>0.05)

Yield Sustenance over Two Years of Cropping within the Fallow Aged Systems

As regards the fallow aged systems, the first year tuber yields were significantly higher in the 7- year fallow system than in the 3-year and 5-year fallow systems (Table 9). The 5-year fallow system produced the least tuber yield of yam in the first year of cropping. In the second year however, there were no significant differences between the fallow aged systems for yam tuber yield. Interms of tuber yield reductions over the two years of cropping, the lowest yield reduction (less than 20%) was observed in the 5-year fallow system. The greatest yield reduction of almost 45% was observed in the 7-year fallowsystem.

Table9. *Percent tuber yield reductions in the three fallow aged systems*

Tuber yield	3-year	5-year	7-year	HSD (0.05)
First cropping tuber yield (t/ha)	31.38b	30.35b	43.16a	10.48
Second Cropping tuber yield (t/ha)	22.78a	25.75a	24.33a	6.62
Yield reduction (%)	27.41	15.16	43.63	

Means with the same subscript within a column do not differ significantly (p>0.05)

Discussion

Effect of Mulches on Soil Physico-Chemical Properties of Fallow Aged Systems

After two years of application of the mulches and yam cropping, soils under *Moringa oleifera* mulch recorded significantly higher contents of total nitrogen and organic matter than under the *Panicum maximum* and *Chromolaena odorata*. This could be due to the fact that *M. oleifera*, as a high quality mulch, decomposed faster as evidenced by the half-life values in the present study to release comparatively larger concentrations of nutrients resulting in subsequent increase in soil fertility [17-22]. Moreover, across the three mulches, there were significant increases in soil pH, nitrogen, and organic matter, calcium, and E.C.E.C levels in comparison to their initial contents. This observation agrees with the findings of Lutaladio *et al*. [23] who indicated that comparatively, significant increases in pH, organic carbon, total nitrogen, available phosphorus, and exchangeable cations (Ca, Mg, K.), are observed after two years of organic mulch application and cropping.

The implication of the present study is that in spite of the fact that yam as a heavy feeder, removed large quantities of soil nutrients upon crop removal, [24-26] appreciable amounts of nutrients were still left in the soil for further cropping, a result arising from the positive effects of the applied mulches [27].

This finding of the present study is an indication of longer periods of sustainable and high production of yam on the same piece of land as against the hit herto maximum of two years spent on the same piece of land. As regards, soil moisture enhancement, there was significantly higher soil moisture content under *M.oleifera* and *C.odorata* than under *P.maximum* mulches during the cropping periods, a situation which could be due to the increased water holding capacity of these soils resulting from the significantly higher soil organic matter contents [27-29] under these two mulches, *M. oleifera* and *C.odorata*.

Effect of Mulches on Growth, Yield and Tuber Physical Quality of Yam in the Fallow Aged Systems

The observed good yam growth under *M.oleifera* mulch in terms of long ervine lengths and greater number of leaves could be attributed to the increased soil organic matter and nutrient contents which enhanced the plant growth [30, 31]. In terms of the fallow aged systems, the 7-year fallow system produced the highest leaf numbers and biggest leaf area index, a result which could be due to the longer period of accumulation of soil organic matter and the subsequent positive effects on plant growth [32]. For tuber yield, *M. oleifera* mulched plants recorded the largest tuber yields, probably due to the high nutrient concentration in the soil under it which ensured good tuber development and filling. On the other hand, yam plants mulched with *C. odorata* and *P. maximum* produced similar tuber yields which might be due to the similarity in the level of nutrient concentrations found in the decomposing mulch materials of the two mulch types.The results of the present study are however at variance with the report of Adeniyan *et al*., [10] who indicated that tuber yield of yam under *C. odorata* mulch was significantly greater than that under *P.maximum.*

Tuber Yield Sustenance under the Mulches

Yam yields under *M. oleifera* mulch over the two year period, recorded the least yield reduction of lessthan 20% where as the yield reduction under the *C.odorata* and *P.maximum* mulches were over 30% and almost 50%, respectively. This implied that the use of *M. oleifera* as mulch could result in a better sustenance of yam yields on the same piece of land over a longer cropping period than the other two mulches. This is the first report of the potential of *M.oleifera* applied as mulch, in ensuring the sustainability of yields of root and tuber crops, for instance yam.

Conclusion

Good soil fertility was sustained under *Moringa oleifera* and *Chromolaena odorata* mulches in spite of cropping of yam, considered as a heavy feeder crop. The high concentrations of nutrients in *M. oleifera*, coupled with its faster rates of nutrient release ensured better growth and higher yields of yam as compared to *C. odorata* and *P. maximum* mulches. A yield reduction in yam was least under *M. oleifera* mulch and therefore could be considered as the best candidate to ensure sustainable yields of yam on the same piece of land for longer cropping periods.

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