

Mini Review

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Yam-Based Cropping Systems Performances with Herbaceous Legumes and Chemical Fertilizers

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Abstract

In West Africa, the traditional yam-based cropping systems (shifting cultivation and slash-and-burn) contribute to the deforestation, land degradation and low soil productivity. With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes (*Aeschynomene histrix* and *Mucuna pruriens* var *utilis*) and chemical fertilizers. This study examines the effect of rotations with herbaceous legumes and chemical fertilizers on yam yields and soils, to see how consistent they are for the different farmers within a site, and different sites. A perennial experiment was implemented for 4 years, with 2-year rotations, smallholder farmers' traditional rotations maize-yam or 1-year *Andropogonon gayanus* (natural fallow)-yam, with rotations intercropped *Aeschynomene histrix* with maize-yam or intercropped *Mucuna pruriens* with maize and chemical fertilizers. The experiment was conducted with 32 farmers, eight in each site (Miniffi, Gomè, Akpéro and Gbanlin). For each of them, we used a randomized block design with four replicates and four crop rotation treatments. The same treatments didn't "work" for all 32 farmers from one year to another. The effects of treatments on yam yields differed significantly for the different farmers within a site, and different sites. Yam has a poor response to mineral fertilizer applications. When natural fallow and maize as precedents were compared, yam yield was higher after a (short) natural fallow, despite the chemical fertilizers supply on maize. Indeed, the decrease in yam yields was slower year after year after fertilized maize compared to natural fallow but yam yields remained the lowest after maize. Soil nitrogen and phosphorus concentrations were improved on different sites on yam-based cropping systems with herbaceous legumes and chemical fertilizers in 0-10cm and 10-20cm depth.

Keywords: Chemical fertilizers; Herbaceous legumes; Production; Soil fertility; Sustainable agriculture

Introduction

Yam (*Dioscorea* spp.) is a tuber crop widely cultivated in the humid and sub-humid lowland regions of West Africa and the Caribbean. More than 90% of the worldwide production (40 million metric tons of fresh tubers year⁻¹) is produced in West Africa [1].

Yam cultivation in West Africa is now confronted with the scarcity of fertile soil available for clearing [2]. In Benin nowadays, farmers hardly have the possibility to rely on long duration fallow and yam is being cultivated in 1 or 2-year herbaceous fallow-yam or maize-yam rotation systems with manual incorporation of residue into the soil.

The decline in yam yields under continuous cultivation has led to the largely accepted conclusion that yam requires a high level

of natural soil fertility (organic matter and nutrient) (O'Sullivan and Ernest, 2008). Since the demand for yam keeps increasing due to the continued population growth, reserves of arable land are diminishing, and fallow duration is decreasing. It is becoming necessary to sustainably increase yam productivity in sedentary cropping systems (O'Sullivan and Ernest, 2008) (Figure 1). There is a dire need therefore to assess in farmers' conditions the economic performance of sustainable cultivation techniques. Ongoing soil degradation could be reduced by the adoption of new farming techniques such as improved fallows of herbaceous legumes [3,4].

With the aim of designing more sustainable yam cropping systems, the agronomic research organization in Benin implemented alternative systems including herbaceous legumes, short natural

fallow and maize plus chemical fertilizers. On the basis of the results of this on-farm research, yam-based systems including herbaceous legumes were diffused. A perennial experiment was implemented for 4 years, with 2-year rotations, smallholder farmers' traditional

rotations maize-yam or 1-year *Andropogonon gayanus* fallow-yam, with rotations intercropped *Aeschynomene histrix* with maize-yam or intercropped *Mucuna pruriens* with maize.

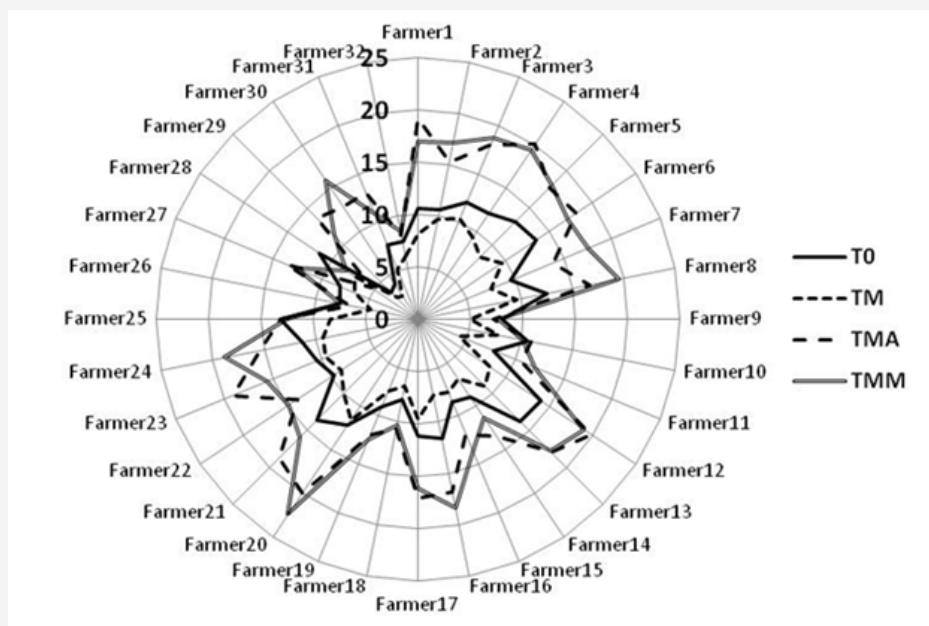


Figure 1: Effect of yam based-cropping systems on yam yield in the 2003 cropping season differed significantly by farmer for the same treatments.

Legend: T0 (control 1): 1-year fallow – yam rotation; TM (control 2): maize with chemical fertilizers – yam rotation; TMA: *A. histrix* /maize with chemical fertilizers intercropping – yam rotation; TMM: *M. pruriens* /maize with chemical fertilizers intercropping – yam rotation;

The objective of this study was to measure the effect of rotations with herbaceous legumes and chemical fertilizers on yam yields and soils, to see how consistent they are for the different farmers within a site, and different sites.

Discussion

The same treatments didn't "work" for all 32 farmers from one year to another. The effects of treatments on yam yields differed significantly for the different farmers within a site, and different sites. The heterogeneity of results should be related to the smallholders' individual effects and practices. If they don't work for some farmers, then is it obvious that those were farmers with relatively poor soil, or who planted late or... In fact crop management (weeding, crop duration, crop density...), site specific conditions (soil organic matter, soil macronutrients, including cumulative amount of rainfall in the 6th month of the yam growing period) could affect yam production [2]. When natural fallow and maize as precedents were compared, yam yield was higher after a (short) natural fallow, despite the chemical fertilizers supply on maize. Indeed, the decrease in yam yields was slower year after year after fertilized maize compared to natural fallow but yam yields remained the lowest after maize (Figure 2). This low residual effect of fertilizers on yam is in accordance with farmers beliefs that yam has a poor response to mineral fertilizer applications as well as with the few experiments conducted on this topic in Benin. Under similar conditions to the present research (rainfall, *kokoro* landrace), Srivastava, Dagbenonbakin and Gaiser [5] did not

find any significant response to mineral fertilizer nor to manure applications on yam cultivated in the central part of Benin (low land use intensity). Gbedolo [6] also reported that experimentation with mineral fertilizers on Benin rarely produced significant results, and that N application resulted in tubers of low organoleptic quality. Similar lack of response was found in both forest transition and savannah areas in Nigeria after application of a range of mineral and organic fertilizers (Ajayi, Akinrinde and Asiedu 2006). However, many experiments concluded otherwise. In Ghana in a forest transition zone where farmers typically plant yam on newly cleared fields, fertilizer applied in several splits did increase tuber yields by 22% without reducing the sensory quality of the product [7]. In Trinidad, Chapman (1965) obtained a 30% increase in tuber yield, under the condition that N application was delayed until three months after planting. Several other works showed positive effects of mineral fertilizers on yam yield [8,9]. Diby et al. [10] in Ivory Coast came to the conclusion that response to fertilizers of both *D. alata*, *D. cayenensis-rotundata* are affected by soil properties. Fertilizer application increased dry matter (DM) production of both species in the savannah site but not in the forest site. Diby et al. [2] also showed that the low yields obtained on soils with low organic matter content were not improved by supplying mineral fertilizer. This would lead to the hypothesis that there are forests soils too rich and savanna soils too poor in organic matter for any response to chemical fertilizers and in between a range of moderately depleted soils where a response can be expected. In the end, the effects of fertilizer supply on yam have to be related to soil organic

matter contents and boundary conditions (climate, agro-ecological zone, soil type, cultivation history) as well as to the fertilizer type supplied and its application and to the crop management practices

[11]. In all, little research has been conducted so far to interpret the response to fertilizers either applied on yam or here on a precedent crop (Table 1).

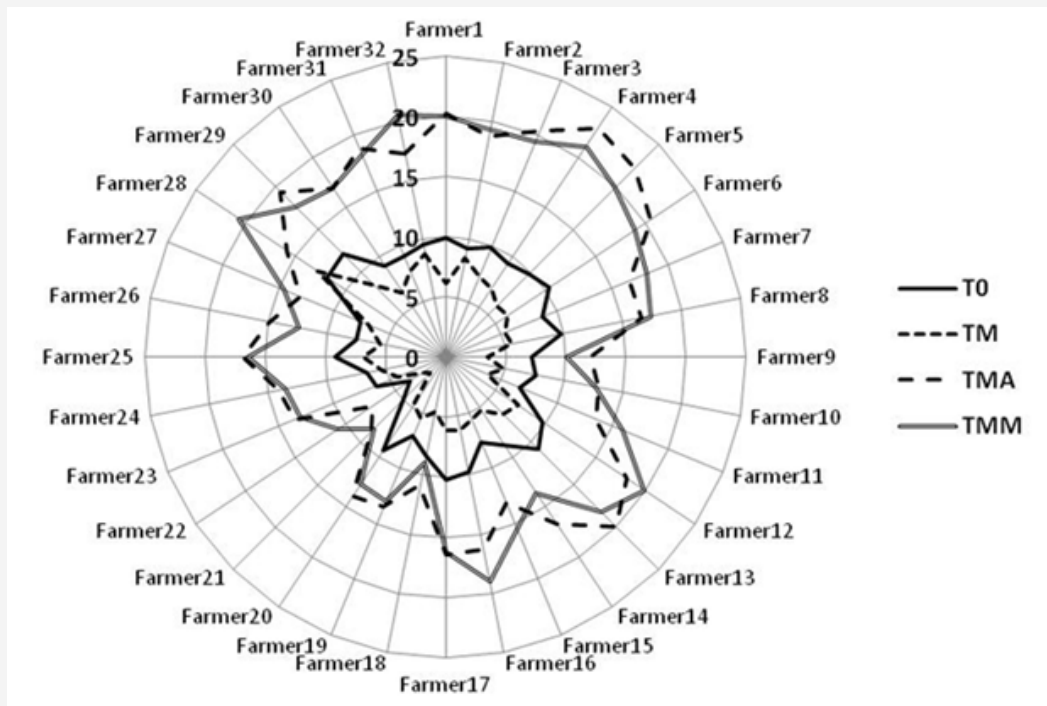


Figure 2: Effect of yam based-cropping systems on yam yield in the 2005 cropping season differed significantly by farmer for the same treatments.

Legend: T0 (control 1): 1-year fallow – yam rotation; TM (control 2): maize with chemical fertilizers – yam rotation; TMA: *A. histrix* /maize with chemical fertilizers intercropping – yam rotation; TMM: *M. pruriens* /maize with chemical fertilizers intercropping – yam rotation.

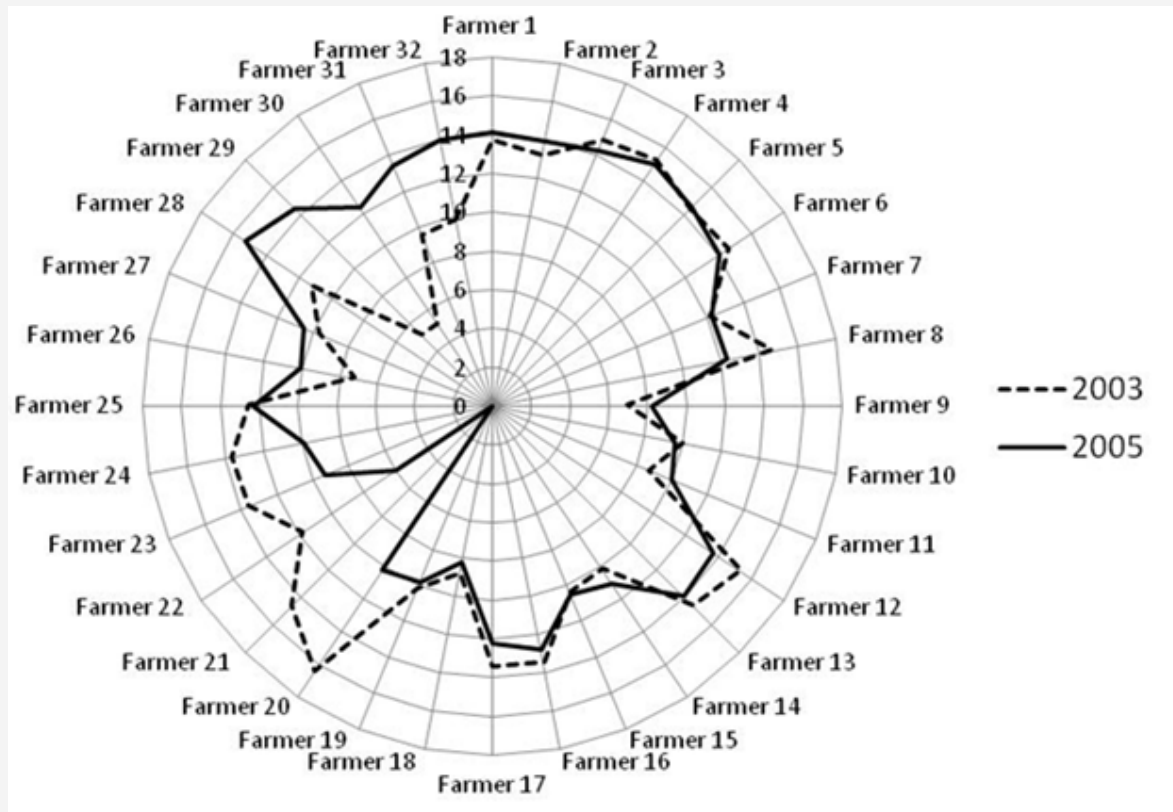


Figure 3: Effect of yam based-cropping systems on yam yield differed significantly by farmer for the same treatments from one year to another.

Table 1: Design of yam-based cropping systems with herbaceous legumes, maize, short fallow and chemical fertilizers in the farmer-managed experiment: 2002-2003 and 2004-2005 cropping seasons, 32 farmers, four village sites (Miniffi, Gomè, Gbanlin and Akpéro), Benin.

Treatments	Year 1 (2002)	Year 2 (2003)	Year 3 (2004)	Year 4 (2005)
T0 (control 1), 1-year fallow – yam rotation	Fallow of <i>A. gayanus</i>	Yam	Fallow of <i>A. gayanus</i>	Yam
TM (control 2), maize – yam rotation	Maize+ N ₁₄ P ₂₃ K ₁₄ + Urea: 100 kg ha ⁻¹ NPK fertilizer (14% N, 10% P, 11.7% K) +50 kg ha ⁻¹ urea (46% N)	Yam	Maize + N ₁₄ P ₂₃ K ₁₄ + Urea: 100 kg ha ⁻¹ NPK fertilizer (14% N, 10% P, 11.7% K) +50 kg ha ⁻¹ urea (46% N)	Yam
TMA (<i>A. histrix</i> /maize intercropping – yam rotation)	<i>A. histrix</i> /maize intercropping + N ₁₄ P ₂₃ K ₁₄ + Urea	Yam	<i>A. histrix</i> /maize intercropping + N ₁₄ P ₂₃ K ₁₄ + Urea	Yam
TMM (<i>M. pruriens</i> /maize intercropping – yam rotation)	<i>M. pruriens</i> /maize intercropping + N ₁₄ P ₂₃ K ₁₄ + Urea	Yam	<i>M. pruriens</i> /maize intercropping + N ₁₄ P ₂₃ K ₁₄ + Urea	Yam

Plot sizes: 10 × 10 m; Harvest plot size: 5 × 5 m; Number of farmers per site: 8; Yam variety tested: "Kokoro" (late maturing *Dioscorea cayennensis* subsp. rotundata; Number of treatments: 4; Number of replications: 4.

Conclusion

The effects of treatments on yam yields differed significantly for the different farmers within a site, and different sites and improved the soil fertility. Yam has a poor response to mineral fertilizer

applications. The heterogeneity of results should be related to the smallholders' individual effects and practices. Collaborations between farmers, research, development and extension structures should be favored to support the development and dissemination of innovations [12,13] (Tables 2&3).

Table 2: Yam and maize yields as affected by the legumes/maize and chemical fertilizers – yam rotations (TMA: *Aeschynomene histrix* intercropped with maize-yam rotation; TMM: *Mucuna pruriens* intercropped with maize-yam rotation) versus the two control rotations (T0 control 1: 1-year *Andropogon* fallow-yam rotation; TM control 2: maize with chemical fertilizers-yam rotation) (4 sites, 32 farmers, Benin).

Treatment	Maize yield DM (t ha ⁻¹)		Yam yield DM (t ha ⁻¹)	
	2002	2004	2003	2005
T0	-	-	5.1 b	4.3 b
TM	1.9 a	1.7 a	3.8 c	3.0 c
TMA	1.9 a	1.5 b	7.2 a	8.0 a
TMM	1.8 b	1.4 c	7.3 a	8.0 a
LSD 5%	0.05	0.04	0.51	0.55
SD	0.16	0.13	2.2	2.7

DM: dry matter

Means with the same letter within column are not significantly different ($p > 0.05$).

Table 3: Soil characteristics at the end of the experiment (December 2005), 0-10 and 10-20 cm layers, four yam-based cropping systems (fallow of *Andropogon gayanus*, maize stover, herbaceous legumes of *A. histrix* and *M. pruriens* var *utilis* intercrops with chemical fertilizers), 32 farmers, four village sites, Benin (all sites confounded).

Soil Characteristics	Depth	T0	TM	TMA	TMM	LSD
Clay%	0-10 cm	5.821c	5.519d	5.944b	5.959a	0.111
	10-20 cm	5.928c	5.611d	6.006b	6.054a	0.124
Silt%	0-10 cm	9.546a	9.678a	9.522a	9.530a	ns
	10-20 cm	9.714a	9.807a	9.670a	9.645a	ns
Sand%	0-10 cm	84.628a	84.802a	84.534a	84.511a	ns
	10-20 cm	84.357a	84.584a	84.324a	84.301a	ns
C%	0-10 cm	0.766b	0.764b	0.818b	0.869a	0.037
	10-20 cm	0.723b	0.703b	0.780a	0.827a	0.033
N %	0-10 cm	0.064d	0.076c	0.086b	0.095a	0.003
	10-20 cm	0.066c	0.085b	0.094a	0.099a	0.004
C: N	0-10 cm	11.947a	10.087b	9.551c	9.032c	0.272
	10-20 cm	11.109a	8.309b	8.319b	8.343b	0.211
MO%	0-10 cm	1.317b	1.313b	1.408a	1.495a	0.063
	10-20 cm	1.244c	1.209c	1.342b	1.422a	0.057

P - Bray I (mg kg ⁻¹)	0-10 cm	10.210c	11.840b	13.430a	14.346 a	1.126
	10-20 cm	8.750c	10.660b	11.410ab	12.290a	1.217
K ⁺ cmol kg ⁻¹	0-10 cm	0.331d	0.424c	0.495b	0.536a	0.026
	10-20 cm	0.266d	0.330c	0.409b	0.453 a	0.028
PH water	0-10 cm	6.063c	6.688b	7.129a	7.031a	0.055
	10-20 cm	6.060c	6.680b	7.144a	6.984a	0.053

Means with the same letter within row are not significantly different ($p > 0.05$)

Legend: C%: soil carbon concentration; N%: soil nitrogen concentration; OM% (= $1.72 \times C\%$): soil organic matter content; C: N: Index of biodegradability or ratio of soil carbon to nitrogen; P. ass. Bray (mg kg⁻¹): soil phosphorus; K⁺ cmol kg⁻¹: soil potassium; LSD: Least square difference at 5%; SD: Standard deviation

T0 (control 1): 1-year fallow – yam rotation; **TM (control 2):** maize with chemical fertilizers – yam rotation; **TMA:** *A. histrix* /maize with chemical fertilizers intercropping – yam rotation; **TMM:** *M. pruriens* /maize with chemical fertilizers intercropping – yam rotation;

LSD: Least square difference at 5%; ns: no significant data are the means.

Source: Maliki et al. (2016)

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Conflict of Interest

The authors declare that there is no financial interest or conflict of interest regarding the publication of this paper.

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