Journal of Agricultural Science and Practice
Volume 5(2), pages 107-118, April 2020
Article Number: CDDF73595
ISSN: 2536-7072
https://doi.org/10.31248/JASP2020.193
https://integrityresjournals.org/journal/JASP

Full Length Research

Demonstrating the efficacy of existing yam technologies in the Forest-Savannah transition zone of Ghana

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Received 20th February, 2010; Accepted 9th March 2020

ABSTRACT: Improved technologies (row planting, ridging, seed treatment, weed management, fertilizer application) with a proven record of sustained productivity for yam production are imperative for food security. This study promotes the efficacy of these existing improved agronomic practices using a farmer-based participatory approach in some selected major yam-growing areas in the forest–savannah transition zone of Ghana. The improved agronomic practice treatment included use of ridging as seedbed, seed treatment before planting, fertilizer application at a rate of 30:30:36 N:P_2O_5: K_2O kg/ha plus 15 kg/ha Mg and 20 kg/ha S as $MgSO_4$ and the use of minimum stakes (trellis; 30-50% fewer stakes used by farmers). This was compared with farmers' practice, which consisted of mounding, no fertilizer application, and no seed treatment. A significantly ($p \leq 0.01$) higher yam yields (more than 60%) were observed for the improved agronomic practice over the farmers' practice at Ejura, Atebubu, and Kintampo which are major yam-growing communities of Ghana. Sensory evaluation showed that the culinary quality of fertilized yam was as good as unfertilized yam. The contribution of existing improved yam production practices in the selected yam communities of Ghana was quantified in terms of their productivity and economic benefit to smallholder farmers.

Keywords: Demonstration, fertilizer, trellis staking, seed treatment, yam.

INTRODUCTION

Yam, an important staple food crop across West Africa, is a major non-traditional export crop in Ghana contributing to about 16% of the national agricultural gross domestic product (Anaadumba, 2013; Ghana Standard Board, 2011). However, several challenges hamper the production and productivity of yam along the value chain. At the vegetative stage, the most limiting constraint is the over-dependency on insufficient rainfall (Kouakou et al., 2019). Other constraints include; low soil fertility, weed infestation, pests and diseases in the field (foliar and soil-borne) (Akwaag et al., 2000; Asiedu et al., 2010). Additionally, insufficient access to quality improved seed, scarce labour and lack of implements for mechanization especially in deforested areas of savannah regions as a consequence of clearing of new lands year after year (Akwaag et al., 2000). The challenges further include drudgery during tillage, slash and burn practice, rodents' attacks (Asiedu et al., 2010). Postharvest issues such as yam rot and lack of proper storage facilities (Ijabo and Uguru, 2019) further poses serious threats.

The current yam production system involve situations where there are annual shifting to new land with yields just around 9 t/ha (FAOSTAT, 2019), 11.4 t/ha (Bhattacharjee et al., 2011) and 10 t/ha (Frossard et al., 2017), far below the 22 t/ha potential yield of *Dioscorea rotundata* (Ennin et al., 2016). Therefore, there is the need to disseminate environmentally sound yam production technologies that increase yield and sustain production on continuously cropped fields particularly as climate change continues to thwart the efforts of farmers from planting to harvest (Ikiriza et al., 2019; Srivastava et al., 2016). In Ghana, crops are already experiencing heat stress, dry spells, pests, and diseases outbreak and shorter planting season as a consequence of the changing climate (Essegbey et al., 2015). Climate change poses a significant threat particularly to the smallholder farmers and to the millions of people who regularly grow rain-fed full season crops such as yam, cocoyam, rice, etc. (Amekudzi et al., 2015; Maliki et al., 2012; Mignouna et al., 2014; Srivastava et al., 2012). Choices about what to grow are often dictated by the ability of the rainfall regime to support soil moisture for plant growth (Oteng-Darko et al., 2018). One way around this would be to breed for improved varieties with shorter crop maturity durations or management interventions that build on the resilience of cropping systems to reduce shocks if the shocks from climate change cannot be done away with.

Evidence however suggests that climate-smart agriculture can contribute to mitigation by supporting more efficient use of fertilizers, weed management and reduced staking options in yam production (Essegbey et al., 2015; Owusu Danquah et al., 2014; Todd et al., 2019). Unfortunately, the adoption and impact of improved yam production practices in Ghana are relatively low. Adoption remains just 6% (Acheampong et al., 2017). For example, Acheampong et al. (2017) report that out of a total of 21 districts in 7 regions across Ghana involving 544 yam farmers nationwide, only 21% of farmers have adopted ridging and 9% uses fertilizer for yam production despite being aware of the technologies. Their results further revealed that as low as 5.9% of yam area was planted with improved yam varieties during the 2014/2015 cropping season. The forest and the guinea savannah zones had the highest proportion of 13% covered with improved yam varieties while only 3.3% of the land area was covered with improved yam varieties in the transition zone (Acheampong et al., 2017).

Only rarely does adoption just happen? Rather, the dissemination and application of innovations need to be planned systematically and comprehensively (Kenyon and Fowler, 2000). Therefore, to stimulate farmers adoption rate of existing improved yam technologies, a 2-years on-farm participatory demonstration (involving farmers, agricultural extension officers, and researchers) of combined seed treatment, ridging, minimum staking option and/or fertilizer application as a package of an existing improved agronomic practice and compared side by side with farmers practice of no seed treatment, sparsely mounding, conventional vertical staking, no fertilizer on farmer's land of the same given area was conducted. The use of ridges plus yam seed treatment help to ensure an optimum number of stands per unit area while the appropriate application of fertilizer (when, how and type) addresses the high nutrient demand of yam and soil fertility challenges (Ennin et al., 2014). The trellis staking option uses ropes and few stakes to address the challenge of scarcity of stakes and cutting of more trees/bamboo for staking (Owusu Danquah et al., 2014). The major objective of the study was to quantify the contribution of existing improved yam production practices or technologies, their productivity, and economic profitability in the selected yam communities of Ghana.

METHODOLOGY

Study sites characteristics

The experiments were conducted in 2015 and 2016 cropping seasons on continuously cropped fields (cultivating year after year on the same piece of land for more than 20 years) at Ejura-Sekyeredumasi, Atebubu-Amantin and Kintampo North districts of Ghana (Figure 1). These areas lie in the forest-savannah transition agro-ecological zone and amongst the major yam growing areas of Ghana (MoFA, 2012). The multistage sampling technique was used to sample the farmers for this study which involved purposive and random sampling techniques. First regions and districts were purposively sampled while yam farmers in communities were randomly selected by designated officers from the Agricultural extension agency of the Ministry of Food and Agriculture organization of Ghana at the selected district. Four farming communities per each operational area and 4 farmers selected from each of these three operational areas were randomly selected from existing farmers-based groups (numbering 8 to 15) for each cropping season by the extension agents (Table 1). Mean annual rainfall (mm) for 2015 and 2016 across locations is shown in the map (Figure 1). The data were sourced from the local district weather stations, which revealed a reduced rainfall in 2016 compared to 2015 with Kintampo communities the most severely affected (Figure 1). Mean annual rainfall (mm) pairs recorded for 2015 and 2016 were 1256:1034, 929:769 and 863:795 at Ejura, Atebubu, and Kintampo respectively (Figure 1). These locations have bimodal rainfall i.e. major rainy season from March to mid-August and the minor rainy season from September to November. Temperature ranges from 25 to 39°C with soil type of Ferric Acrisol; grayish brown sandy loam topsoil of dark brown gritty clay loam (Adjei-Gyapong and Asiamah, 2002).

Experimental design

A Randomized complete block design with 4 replications was used for the study. A total of 24 trials were established in all the operational areas (Table 1). Twelve (12) trials were established in the 2015 cropping season. Another 12 trials were again repeated in the 2016 cropping season at the same locations but in different fields. Farmer's own choice and preferred local white yam variety (*Dioscorea*

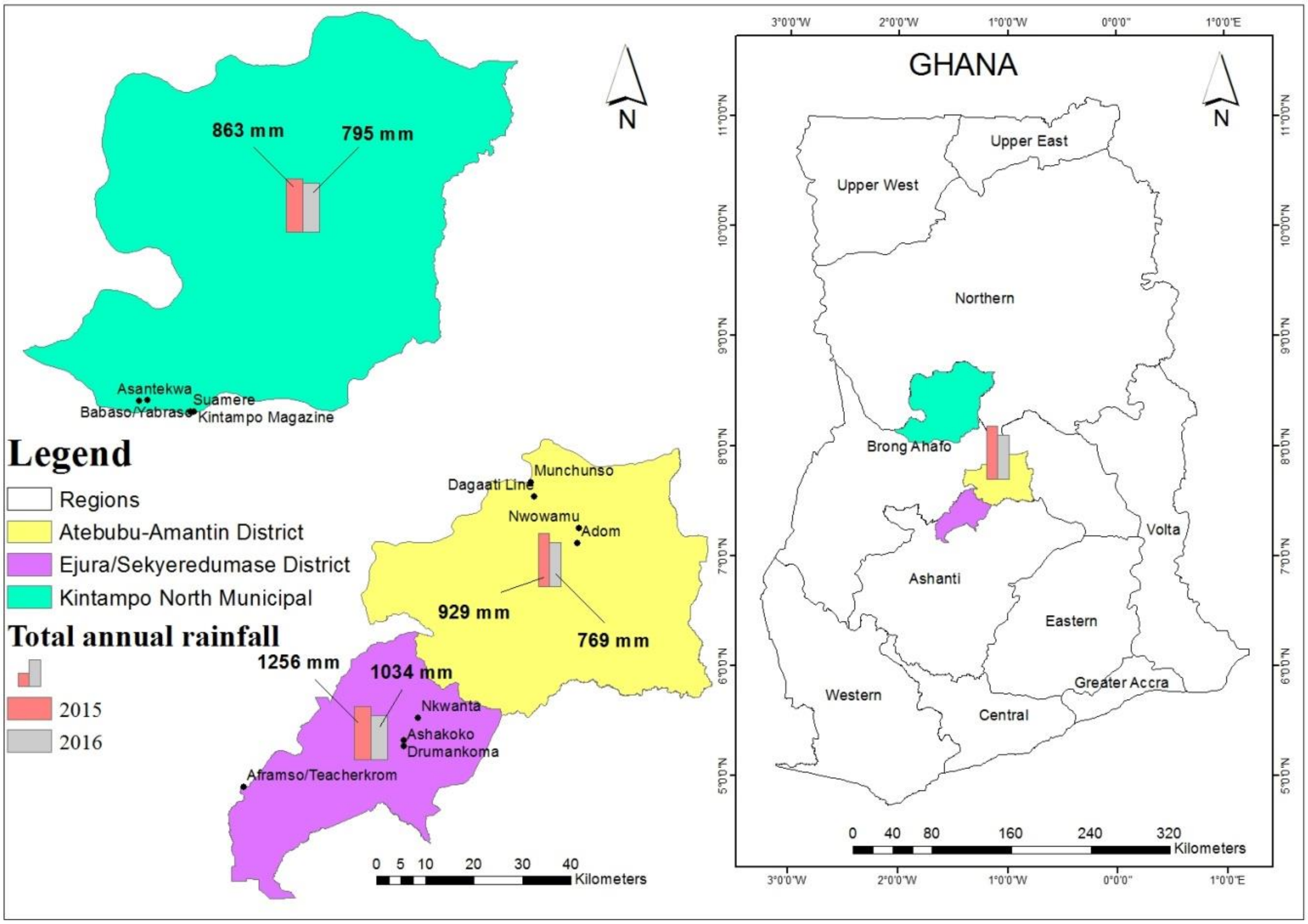

Figure 1. Map of Ghana on the (right), zoomed in on Ejura-Sekyeredumasi, Atebubu – Amantin and Kintampo North districts (left) of the forest-savanna transition zones. Specific farming communities where the studies were undertaken for 2015 and 2016 cropping seasons are illustrated with dots (●) on the respective district map with their names beside. Mean annual rainfall (mm) per location is depicted by bar plots for each cropping year.

Table 1. Farmers ID and their respective planting dates for each of the operational areas of the study in 2015 and 2016 cropping seasons.

Year	Atebubu			Ejura			Kintampo		
	Farmer ID	**Planting Date**	**Community**	**Farmer ID**	**Planting Date**	**Community**	**Farmer ID**	**Planting Date**	**Community**
2015	AA	2-Jun	Adom	AE	11-Jun	Aframso/Teacherkrom	AK	21-Jun	Asantekwa
	BA	5-Jun	Dagaati Line	BE	11-Jun	Ashakoko	BK	21-Jun	Suamre
	CA	6-Jun	Munchunso	CE	11-Jun	Dromankuma	CK	21-Jun	Babaso/Yabraso
	DA	4-Jun	Nwowamu	DE	12-Jun	Nkwanta	DK	21-Jun	Kintampo Magazine
2016	EA	4- Jun	Adom	EE	1-Jun	Aframso/Teacherkrom	EK	9-Jun	Asantekwa
	FA	5-Jun	Dagaati Line	FE	2-Jun	Ashakoko	FK	10-Jun	Suamre
	GA	5-Jun	Munchunso	GE	3-Jun	Dromankuma	GK	10-Jun	Babaso/Yabraso
	HA	4- Jun	Nwowamu	HE	1-Jun	Nkwanta	HK	9-Jun	Kintampo Magazine

rotundata Poir), "Dente", was planted and subjected to two treatment applications from the start of planting till harvest. For anonymity and to still demonstrate the participatory nature of the study, farmers were randomly selected by the various local agricultural extension agents of the Ministry of Food and Agriculture of Ghana from each of the 3 operational areas and identified in concealed letters (Table 1). Planting of yam across these locations started at the beginning of June and completed by 21st of June each year (Table 1). Harvesting of yam was completed by the end of December of each year. The treatments were the existing improved agronomic practices as established by Ennin et al. (2014), Ennin et al. (2016), Hgaza et al. (2010), Owusu Danquah et al. (2014) and local technology/ farmers' practice. The improved agronomic practice for yam production included a package of; treating yam seed before planting with fungicide and insecticide, weed management, use of ridging as seedbed, fertilization at 30:30:36 N: P_2O_5: K_2O Kg/ha plus 15 Kg/ha of Mg and 20 Kg/ha S as $MgSO_4$ and use of trellis for staking whiles the farmers' practice allowed farmers to use their local technology. Specifically, farmers' practice was characterized by planting on mounds without pre-treating of seed against insects, without fertilizer application and conventional vertical staking. Continuously cropped fields cultivated for more than 25 years, inherently poor in macro and micronutrients and acidic in which hitherto, farmers would not culturally choose as fit for yam production (Hgaza et al., 2010) were selected in each operational area for the study. The rationale behind promoting yam cultivation on continuously cropped fields is to demonstrate its ability to support yam production, through the use of improved yam agronomic technologies to progressively hasten a reduction in the clearing of new fields year after year. Each improved agronomic field had an area of 0.1 ha planted at 1.2 m inter-row and 0.8 m intra-row on the ridges resulting in 10,416 stands/ha.

The same size of 0.1 ha was demarcated for the farmers' practice where they mounded sparsely to cover the entire field of just about 4,000 stands/ha. Each farmer field was considered as a replicate. The fertilizer treatment for the improved agronomic practice fields was applied at 50% split, first at 5 to 6 weeks and later 11 to 12 weeks after planting in all the locations, exemplified in similar yam agronomic studies undertaken by Owusu Danquah et al. (2018a). Sett sizes of about 200 g of the improved agronomic fields were treated with Dursban (Chlorpyrifos from Dow Agro Sciences; 1.25 L/ha) and Mancozeb (Dithiocarbamate from Ag-Chem Africa 80%; 75 g in 15 L of water) before planting. Farmers' sett sizes of about 350 g on the average which in some cases was double of what was used in the improved agronomic fields were planted without any seed pre-treatment. This is a normal practice for most farmers from these localities as they tend to cut their seed yam bigger enough to expect bigger tubers at harvests (Owusu Danquah et al., 2018b). Emerged weeds in the improved agronomic fields were controlled with glyphosate (2.5 liters per ha) before the sprouting of the yam while farmers only slashed on their fields. Thereafter, weeds were manually controlled with cutlass and hoe in either improved agronomic field or farmers' field. In 2016, sensory evaluations were conducted with 50 participants [an acceptable value to conduct in-ground theory studies- Marshall et al. (2013)] from the nearby communities across all areas after eating boiled yam (arguably one of the common food products from yam across West Africa (Otegbayo et al., 2005) during harvest in December. Fertilized and unfertilized boiled yam (coded at the blind side of the participants) using one questionnaire interviews, farmers scored for taste, texture, aroma, and acceptability.

Data collection and analysis

During harvest, the tubers were grouped into two; ware yam (tuber sizes of more than 500 g) and seed yam (500 g and below) and weighed separately for each of the practices. Four replications from each operational area (Ejura, Atebubu, and Kintampo) and across the two seasons (2015, 2016) were subjected to statistical analysis. Data on stand harvested, the weight of ware yam, weight of seed yam and total yam yield collected were subjected to one-way analysis of variance linear model at 5% significant level using 'R' statistical software. Where treatment means differ, Tukey's HSD test was used to group them and visualized with bar graphs using MS excel 2010. Percentage differences of total yam yield harvested between the improved practice and the farmers' practice were calculated based on the formula:

$$\text{Percentage difference} = \frac{\text{IAP} - \text{FP}}{(\text{IAP} + \text{FP})/2} \text{x}100$$

Where: IAP = improved agronomic practice and FP = farmers practice

To deduce return on investment after venturing in any of the practices, benefit-cost ratio (widely recommended for agricultural enterprise (Shively, 2013) as a valuable economic indicator to summarize the overall value for money of a proposal for decision making) was subsequently calculated for the 3 locations and years using yam yield and farm gate price per kg of yam at harvest. Yam tuber yields obtained were adjusted 10% downwards to account for tuber quality reduction as a result of tuber breakages.

RESULTS AND DISCUSSION

Influence of improved yam agronomic package on tuber yield

Although smaller seed sett sizes of about 200 g were used on the improved yam agronomic practice fields, total yam

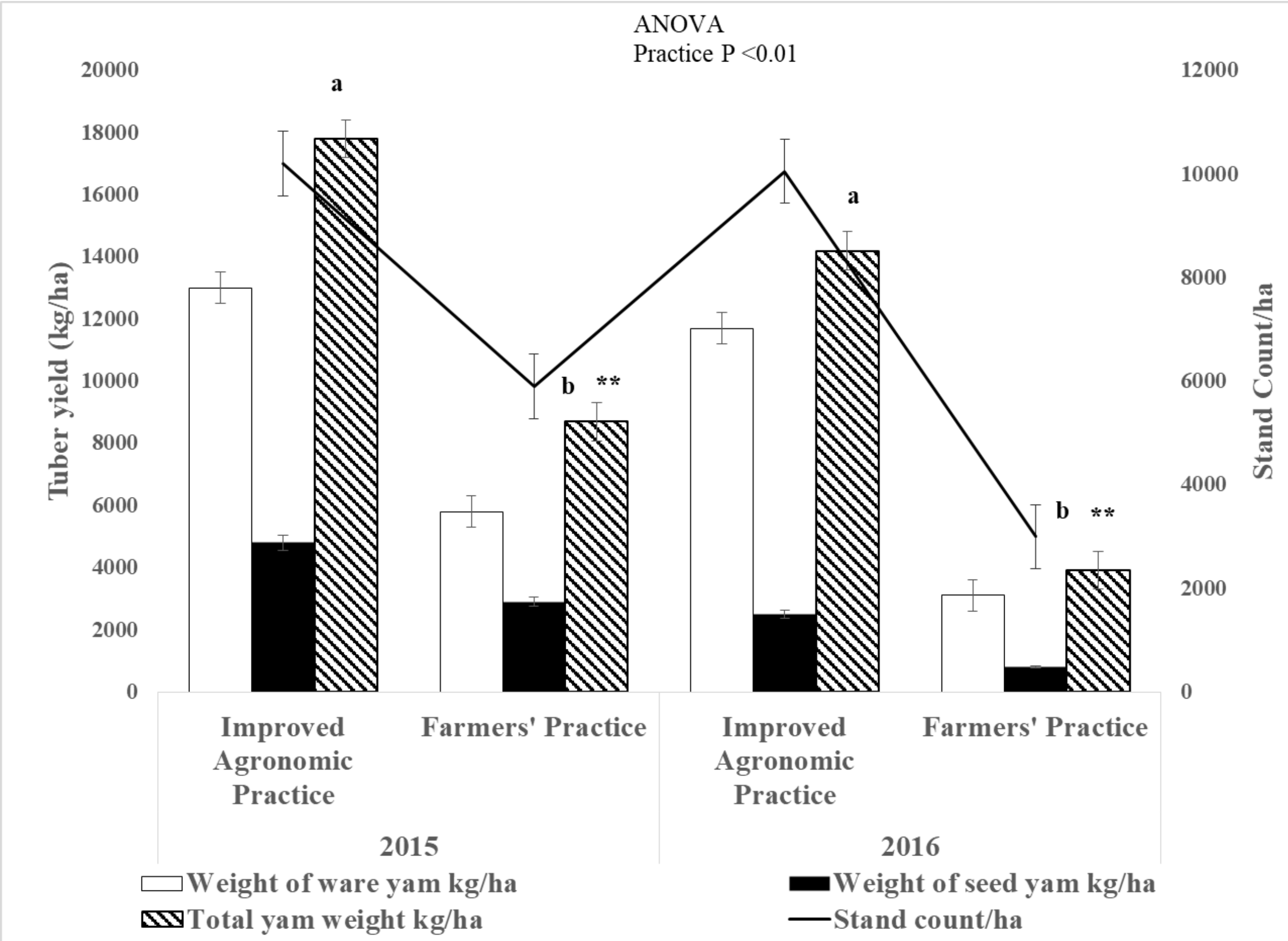

Figure 2. Yam tuber yields and stand count as influenced by improved agronomic practice and farmers' practice in the Ejura farming communities for 2015 and 2016 cropping seasons. Mean values and standard errors (n = 4) are plotted. Index letters above the bars indicate significant differences ($p < 0.01$) between media not sharing the same letter by Tukey's HSD test. Asterisks indicate significant differences ($p < 0.01$) between the two practices.

tuber yields were however significantly ($p < 0.01$) higher compared to the farmers' practice which used bigger seed sett sizes of more than 350 g. Bigger seed sett sizes do not necessarily translate into significantly higher yield but planting density and agronomic management are observed to be vital in total yam yield (Owusu Danquah et al., 2018b). Improved yam practice generated at least 7 t/ha more yields across all locations and cropping seasons (Figures 2 to 4). Plant stand on a per hectare basis in the improved agronomic practice was 10,416 compared to about 4,000 on farmers' practice fields. This was as a consequence of ridges used in the improved agronomic practice. Ridging in yam production allows more stand per ha without compromising overall yield compared to conventional sparsely moulded mounds (Ennin et al., 2009; Ennin et al., 2014). Similar to reports by Ennin et al. (2009), it was observed that tubers harvested from the ridges were oblong-shaped while tubers from the mounds were cylindrically shaped though bigger (Plate 1.). Tubers harvested from ridges tend to be medium-sized between (1.5 to 2 kg/tuber) which are mostly preferred by the export market when shipping a 25 kg box of other white yam variety containing 14 to 16 tubers [averaging 1.6 and 1.8 kg/tuber] (Owusu Danquah et al., 2018a; Ghana Standard Board, 2011). Again, Ennin et al. (2014) emphasized that ridging interacting with fertilizer application results in higher yields compared to farmers' practice of manual mound construction with no fertilizer. Therefore, as expected, the use of improved agronomic package of ridging, yam seed pre-treatment, trellis staking and fertilizer rate of 30:30:36 N: P_2O_5: K_2O kg/ha plus 15 kg/ha Mg and 20 kg/ha S as $MgSO_4$ resulted in total tuber yield percentage difference of more than 65% across locations over farmers' practice for the 2015 cropping season (Figure 5). Tuber yield percentage differences for the 2016 cropping season between the two practices were 113.6, 113.9 and 120% at Ejura, Atebubu and Kintampo farming communities respectively (Figure 5). Similar to earlier recommendations by Asiedu et al. (2010) and Bhattacharjee et al. (2011), seed treatment for pests and

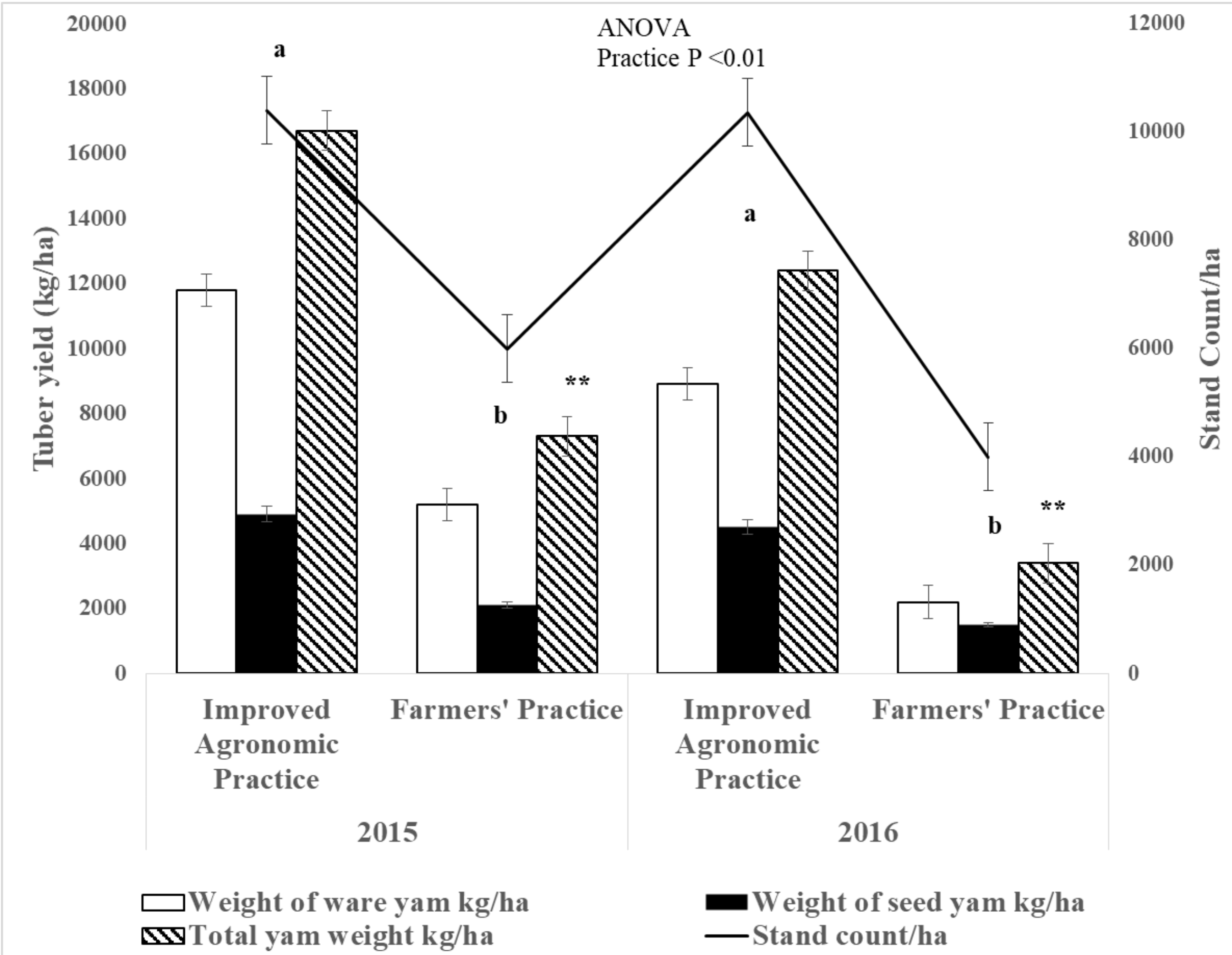

Figure 3. Yam tuber yields and stand count as influenced by improved agronomic practice and farmers' practice in the Atebubu farming communities for 2015 and 2016 cropping seasons. Mean values and standard errors (n = 4) are plotted. Index letters above the bars indicate significant differences (p < 0 .01) between media not sharing the same letter by Tukey's HSD test. Asterisks indicate significant differences (p < 0.01) between the two practices.

diseases before planting promotes sprout rate thus ensuring improvement in achievable stand density culminating into overall high yam productivity.

Ridging has the potential to reduce drudgery and increase the scale of production through mechanization, and improve fertilizer use efficiency (Ennin et al., 2016; Ennin et al., 2014). However, the challenge with ridging in Ghana as recommended by Ennin et al. (2014, 2016) is that emphasis be put on ensuring that mechanized-ridgers are accessible for purchase or ridging provided as a hired service by farmers. One may have expected less productivity from the improved practice fields due to shading by the dense population. However, this was not the case as the trellis staking option employed in the improved technology just like the vertical staking by farmers allowed the vines and leaves to climb and get exposed to enough sunlight thus avoiding shading and reducing competition. This had earlier been reported in the work done by Ennin et al. (2014) and Owusu Danquah et al. (2014) that trellis/minimum staking with stakes taller than 1.5 m high of yam planted on ridges has the potential for higher profit even than farmers' current staking practices and planting on mounds. Overall, the yield differences were more than 60% between the improved agronomic practice and farmer's practice from Ejura, Atebubu and Kintampo yam growing communities of Ghana (Figure 5). Generally, yields were higher in 2015 than in the 2016 cropping season (Figures 2 to 4). Higher rainfall during the 2015 cropping season (Figure 1) might have contributed to yam establishment, nutrient availability to plants and increased overall productivity compared to 2016.

Erratic rainfall and prolong drought require technologies that enable the soil to conserve moisture and promote nutrient use efficiency to increase the resiliency of any cropping system. Similar to studies suggesting that

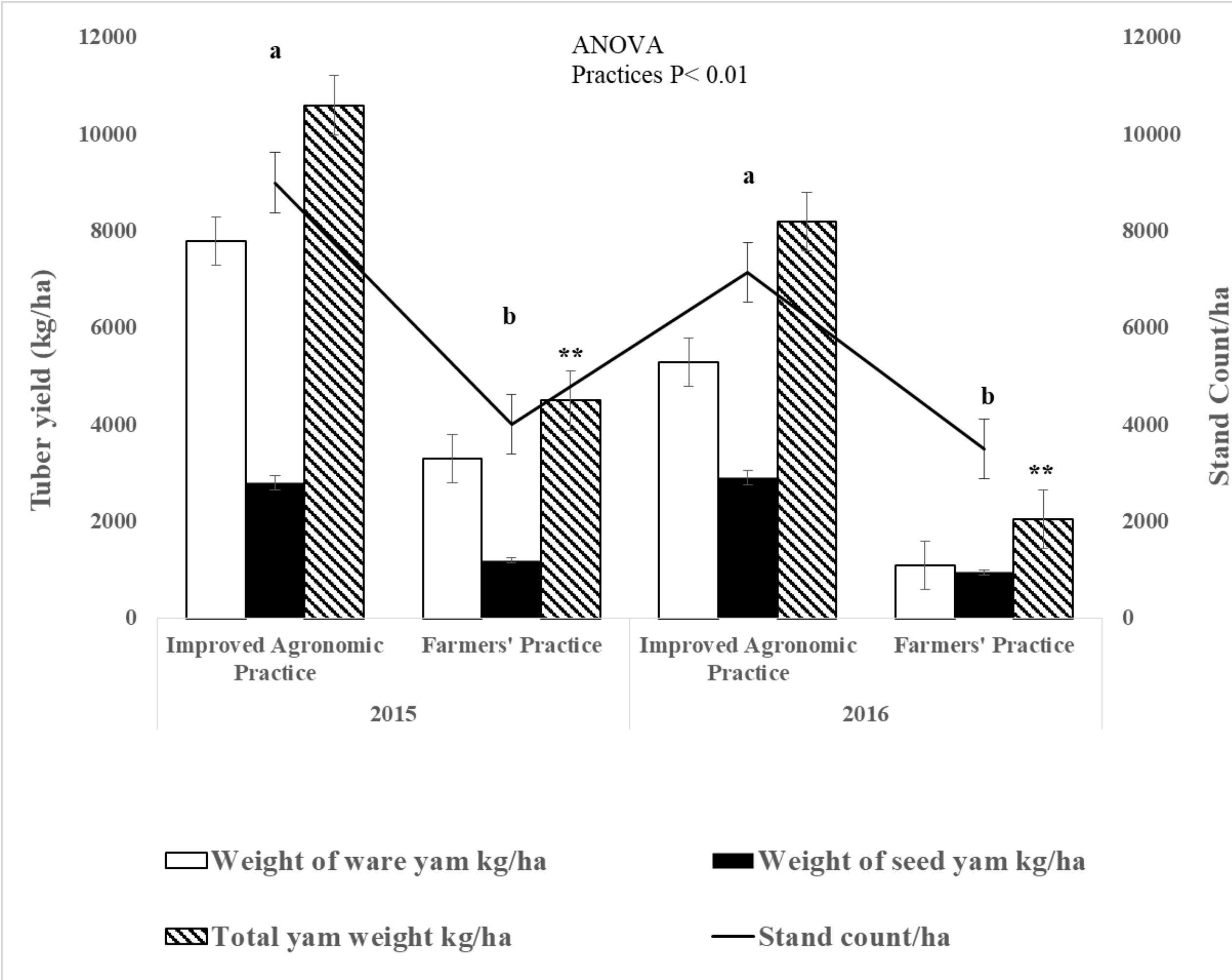

Figure 4. Yam tuber yields and stand count as influenced by improved agronomic practice and farmers' practice in the Kintampo farming communities for 2015 and 2016 cropping seasons. Mean values and standard errors (n = 4) are plotted. Index letters above the bars indicate significant differences (P < 0.01) between media not sharing the same letter by Tukey's HSD test. Asterisks indicate significant differences (P < 0.01) between the two practices.

planting on ridges maintains optimum plant stands and conserve moisture than sparsely moulded mounds (Ennin et al., 2014; Ennin et al., 2016; Owusu Danquah et al., 2014), higher yield differences (more than 60%) was recorded (Plate 1 and Figure 5). Ridging allows linear and precise arrangement, uses available space efficiently, thus promotes nutrient efficiency upon application of fertilizer compared to farmers' sparsely moulded mounds. Prior studies by Ennin et al. (2014) made a similar argument with planting on ridges which significantly had greater yield response to fertilizer than on sparsely moulded mounds.

However, it was noted that tuber yields seem closer or even lower than the current reported average yield of about 9 t/ha (FAOSTAT, 2019) and 10 t/ha (Frossard et al., 2017) for the year 2016 cropping season at Kintampo (Figure 4) when the average annual rainfall mean was less than 800 mm at Kintampo (Figure 1). The choice of continuously cropped fields/land with at least 20 years of constant cultivation with different crops, myriad of crop rotation cycles and cropping system for this study might be the possible explanation for this observation. These are fields/land hitherto farmers ordinarily would not select for the cultivation of yam. Also, the reported tuber yields of 9 to 10 t/ha mainly resulted from yam cultivated on newly cleared fields richer in nutrients than the continuously cropped fields used in this study. Thus, this study demonstrates that yam production can be sustained on continuously cropped fields to produce yields similar to planting on the newly cleared field.

Furthermore, the productivity of the improved agronomic practice fields for the 2016 cropping season (Figures 1 to 5) with reduced rainfall (<800 mm) across all locations illustrates the level of resilience of the improved agronomic technology. Despite the increase in the yield of yam when fertilized and weeds controlled with glyphosate, there are complaints and concerns by some consumers and farmers

Plate 1. Harvested yam from the two practices. Yam was grouped into ware and seed yam based on their sizes. Letter 'A' is yam harvested from the improved agronomic practice while letter 'B' is yam harvested from the farmer's practice.

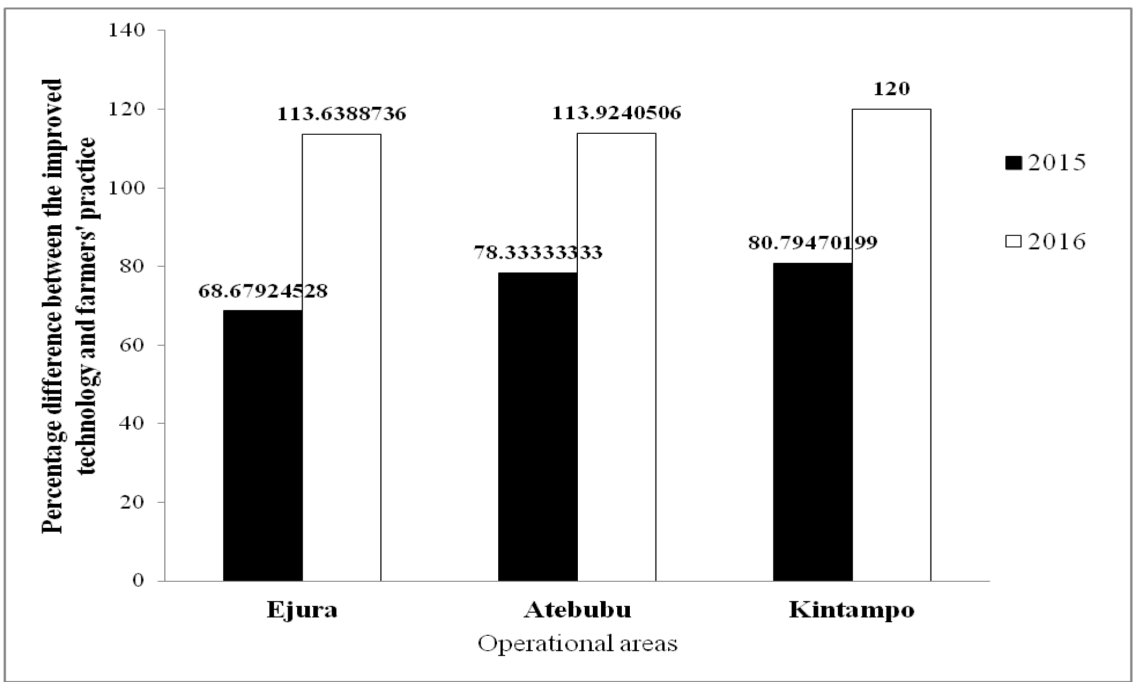

Figure 5. Percentage differences between the two practices across two seasons calculated for each location based on their total yam yield (kg/ha).

in the public space that fertilizing yam or use of glyphosate (herbicide) leads to rots and reduces the overall shelf life (Aidoo et al., 2018; Wumbei et al., 2019). Conversely, an investigation by Aidoo et al. (2018) however recorded similarities in the incidence of rot among fertilized and unfertilized white yam treatments. Their research found no significant differences in terms of rot severity among the fertilizer application models as well as the control. They further argued that varietal differences and tuber sizes were key factors identified as having a significant effect on yam storage rots (Aidoo et al., 2018). Also, Wumbei et al. (2019) concluded in their study that there were no differences in yam rot and yield between herbicide treated and manually weeded yams, but certain n varieties (e.g.,

Table 2. Benefit-cost analysis of improved agronomic practice vs. farmers' practice in Ejura, Atebubu, and Kintampo.

Location	Ejura operational area				Atebubu operational area				Kintampo operational area			
Practice	Improved agronomic practice	Farmers' practice	Improved agronomic practice	Farmers' practice	Improved agronomic practice	Farmers' practice	Improved agronomic practice	Farmers' practice	Improved agronomic practice	Farmers' practice	Improved agronomic practice	Farmers' practice
Year	2015	2015	2016	2016	2015	2015	2016	2016	2015	2015	2016	2016
Average yield (kg/ha)	17800	8700	14200	3910	16700	7300	12400	3400	10600	4500	8200	2050
Adjusted yield (kg/ha)	16020	7830	12780	3519	15030	6570	11160	3060	9540	4050	7380	1845
Farm gate price in December each year (₵/kg)	1.4	1.4	1.45	1.45	1.3	1.3	1.4	1.4	1.2	1.2	1.2	1.2
Gross benefit(₵/ha)	22428	10962	18531	5102.55	19539	8541	15624	4284	11448	4860	8856	2214
Cost of chemical fertilizer, glyphosate, fungicide & pesticide (₵)	355	0	355	0	355	0	355	0	355	0	355	0
Labor cost for application of fertilizer & others (₵/ha)	153	0	153	0	153	0	153	0	153	0	153	0
Cost of land clearing and stomping (₵/ha)	320	0	320	0	290	0	290	0	300	0	300	0
Construction of ridges (₵/ha)	300	0	300	0	300	0	300	0	300	0	300	0
Construction of mounds (₵/ha)	0	200	0	200	0	250	0	250	0	240	0	240
Cost of seed yam (₵)	955	455	955	455	955	455	955	455	955	455	955	455
Labor cost of planting(₵/ha)	161	139	161	139	160	140	160	140	160	140	160	140
Cost of stakes(₵/ha)	392	282	392	282	392	282	392	282	392	282	392	282
Labor cost of staking(₵/ha)	400	460	400	460	415	500	415	500	405	470	405	470
Cost of weeding and reshaping(₵/ha)	675	675	675	675	675	675	675	675	600	600	600	600
Harvesting cost(₵/ha)	182	153	182	153	182	153	182	153	182	153	182	153
Total cost that vary (₵)	3893	2364	3893	2364	3877	2455	3877	2455	3802	2340	3802	2340
Net benefit (₵)	18535	8598	14638	2738.55	15662	6086	11747	1829	7646	2520	5054	-126
Benefit cost/Ratio	4.76	3.64	3.76	1.16	4.04	2.48	3.03	0.75	2.01	1.08	1.33	-0.05

NB: Average yield adjusted 10%. Conversion ratio - Gh₵ 1.00 = $ 0.19.

Pona) were more rot susceptible. Drawing from these investigations, we would suggest careful genomic analysis and molecular studies on the yam rot trait among more susceptible varieties vs. less susceptible types to elucidate the potential yam rot linkages to variant alleles or loci.

Partial budgeting and cost-benefit analysis

Table 2 presents the partial budgeting and cost-benefit analysis of white yam production under improved agronomic practice and farmers' practice at Ejura, Atebubu, and Kintampo operational areas. The results revealed that irrespective of location or the season, yam planted with the improved agronomic practice had a higher benefit to cost ratio compared to farmers' practice. The benefit to cost ratios for improved technology: farmers' practice of 4.76:3.64, 4.04:2.48 and 2.01:1.08 were achieved for Ejura, Atebubu and Kintampo communities respectively for the 2015 cropping season (Table 2). Thus, when a farmer invests $1.00 (at a conversion ratio of Gh₵ 1.00 = $ 0.19) in yam production using the recommended improved technology, a profit of $ 0.71, $ 0.58 and $ 0.19 would be accrued in addition to the $1.00 invested capital at Ejura, Atebubu, and Kintampo respectively during the 2015 season. During the 2016 cropping season, drought was more intense particularly for Atebubu and Kintampo areas (Figure 1). However, the benefit to cost ratio for using the improved agronomic practice was still

Table 3. Sensory evaluation of fertilized and unfertilized boiled yam involving farmers from Atebubu, Ejura, and Kintampo farming communities.

Location	Treatment	Taste	Texture	Aroma	Overall acceptability	STD acceptability
Atebubu	Fertilized yam (30 30 36 N-P205-K20 (Kg/ha) + 20kg S & 15kg 15 Mg as MgSO4)	2.30	2.5	2	2.20	0.87
	Unfertilized yam (0kg/ha)	2.60	2.5	2.4	2.50	0.86
Ejura	Fertilized yam (30 30 36 N-P205-K20 (Kg/ha) + 20kg S & 15kg 15 Mg as MgSO4)	2.90	2.9	2.8	2.80	0.91
	Unfertilized yam (0kg/ha)	2.90	2.9	2.8	2.80	0.91
Kintampo	Fertilized yam (30 30 36 N-P205-K20 (Kg/ha) + 20kg S & 15kg 15 Mg as MgSO4)	2.10	2.2	2.4	2.20	0.81
	Unfertilized yam (0kg/ha)	2.70	3.3	3.1	3.10	0.97

n=50, Score Scale 1-5; 1=best, 5=worst.

better, thus achieving benefit-cost ratios of 3.76, 3.03 and 1.33 compared to 1.16, 0.75 and loss of 0.55 for using farmers practice at Ejura, Atebubu and Kintampo communities respectively (Table 2). Thus, a profit of $ 0.52, $ 0.39 and $ 0.06 would be accrued in addition to the $ 1.00 invested capital upon the use of improved agronomic practices at Ejura, Atebubu, and Kintampo respectively. The use of the farmers' practice resulted in a total loss of $ 0.29 in the Kintampo area (Table 2). This suggests that the use of the improved agronomic practice would not only increase and sustain yields on continuously cropped fields but also the best option during drought spells, erratic and reduced rainfall conditions. The improved agronomic package thereby increases farmer's resilience in dealing with such harsh weather conditions and ensure returns on their investments.

Influence of fertilizer on the taste of yam

The results of this study confirmed previous reports by Ennin et al. (2014) that fertilizer does not affect the taste quality of yam. White yam planted in 2016 under the improved agronomic practice (fertilized) and farmers' practice (unfertilized) was boiled after harvest and given to 150 participants, 50 each from Atebubu, Ejura, and Kintampo who were largely farmers for sensory evaluation (Table 3). Overall, the 150 participants involved were not previewed as to whether the yam they evaluated at a given time was fertilized or unfertilized as they were coded to avoid bias. Participants assessed the various boiled yam on three culinary qualities: 'taste', 'texture' and 'aroma' based on their individual preferences from a scale of 1 up to 5 with 1 being the best score and 5 as the worst after eating (Table 3). Overall acceptability and STD acceptability on the three traits; taste, texture, and the aroma was subsequently calculated following the approach of Ennin et al. (2014). The results were in line with previous evaluation by Ennin et al. (2014) that, contrary to the view that the use of fertilizer in yam production affects the quality of yam, the sensory evaluation showed that the culinary qualities of fertilized yam is good and perhaps maybe even better than unfertilized yam.

Conclusion and policy implication

The contribution of improved yam production practices or technologies in the selected yam communities of Ghana was quantified to be productive and profitable. Thus, existing improved agronomic practices proved to be a more viable option considering the overall significant tuber yields which generally were more than 60% compared to farmers' practices for the two seasons and across locations despite the reduction in mean annual rainfall in those years. The overarching difference between what farmers do today and the improved agronomic package tested is the intensification drive and higher use efficiency (staking, nutrient, soil moisture conservation, improved sprouting) of the technology. The improved agronomic practice allows optimum planting density due to the combined effect of the linear arrangement of ridging, trellis staking, and seed treatment. Since variety and tuber size has been identified as the key drivers of yam rot and not fertilization or herbicide application, it is suggested that a careful genomic analysis and molecular studies on the yam rot trait among more susceptible varieties vs. less susceptible types to elucidate potential yam rot linkages to variant alleles or loci. Development agencies, local and central government must consciously target up-scaling through demonstrations of existing improved yam agronomic technologies to stimulate adoption, promote sustainable yam production thereby addressing deforestation associated with yam production by smallholder farmers.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

ACKNOWLEDGMENT

We thank the Bill and Melinda Gates Foundation who provided the funds for this research work through the YIIFSWA project that was coordinated by IITA, Nigeria through CSIR-Crops Research Institute. We are grateful to the Resource and Crop Management Division's Technical Staff of the CSIR – Crops Research Institute. Thanks to Dr. Enoch Bessah for developing a map and illustrating rainfall for the study area. The invaluable support in data acquisition by Mr. Henry Azotibah and Mr. Augustine Kyeremeh, agriculture extension officers, all of MoFA at Ejura and Atebubu respectively are duly acknowledged.

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