Agronomic and economic performance of seed yam production using minisetts in the middle belt of Nigeria

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Abstract

White yam (*Dioscorea rotundata*) is an important tuber crop of West Africa and the Caribbean, and one the key limiting factors in its production is the availability of good quality planting material. The Adaptive Yam Minisett Technique (AYMT) was designed to help overcome this constraint. The paper presents an analysis of agronomic and economic data collected across four years (2013 to 2016) of AYMT plots planted in two areas within the middle-belt of Nigeria. Of the 136 plots that were established, 11% were lost to flooding and damage from Fulani cattle. Mean yield was 13.16 t/ha, 17,747 tubers/ha and the mean tuber weight was 0.73 kg. Plot yield declined with an increase in planting time, while plots owned by female farmers were on average planted later than those owned by their male counterparts; this helps explain the effect of gender noted in a previous study. Differences in yield were also noted between the two areas, which could also partly be explained by differences in planting time. The plots were profitable, with a mean cost over the four years of Naira 915,196/ha, revenue of Naira 3,197,786/ha and gross margin of Naira 2,282,591/ha (equivalent to US$4,039, US$14,319 and US$10,280 respectively). The main factor influencing costs and revenue was year, with no effect of gender. There is a need for more research on planting time in AYMT and how it interacts with factors, such as yam variety.

Keywords: Adaptive Yam Minisett Technique, gender, planting date, planting material, labor

Introduction

White yam or Greater Yam (*Dioscorea rotundata*) is an important tuber crop of West Africa and the Caribbean. One of the limiting factors in its production is the availability of good quality planting material, mostly in the form of small tubers (seed yams) or pieces of tuber (setts). The vegetative form of yam propagation does allow pests and diseases to be carried from one season to the next, and this can result in serious losses of yield as well as reductions in tuber quality and economic value. In addition, if a large tuber is cut to produce setts, there is greater exposure to pests and diseases. Also, there is a limit as to how many setts can be produced by a large (mother) tuber, especially as the smaller the sett, the smaller the tuber it produces.

Various initiatives have been introduced during the past decades to help address the limitation imposed by the availability of planting material. One approach has focussed on the use of 'minisetts' (Iwueke et al. 1983; Orkwor and Asiedu, 1998), setts in the range of 10 to 80 g, cut from a larger 'mother' tuber. The minisetts are used to produce seed yams. The classic form of this approach was developed and promoted in Nigeria from the late 1970s, and involved the sprouting of yam minisetts (25 g) treated with a pesticide dust and/or woodash in a nursery before transplanting to meter ridges in the field at a spacing of 25 cm (Kalu et al., 1989). Various studies have shown that adoption of the 'Yam Minisett Technique' (YMT) in its entirety by farmers has been mixed, although assessing what is meant by 'adoption' can be a challenge. Does adoption mean a farmer has to adopt the whole package or can he/she take on board some of it? A summary of YMT adoption studies is shown in Table 1, and the average level of adoption across these studies is 31%. However, it should be noted that the results are highly variable and site-specific and this may in part be explained by differences in the way ‘adoption’ was assessed.

While the YMT has been extensively promoted by extension services in West Africa, an issue often identified by farmers is the relatively small sett size, which means that germination takes place in a nursery before transplanting, which increases the labor input for the farmer and adds to the risk, as small setts may not germinate and survive as well as larger setts. Given that yam tubers are relatively expensive, the farmer could lose out if the setts do not survive.

<Table 1 near here>

More recent approaches, notably the Adaptive Yam Minisett Technique (AYMT), have sought to improve adoption by eliminating the nursery stage (Morse et al., 2009; Morse and McNamara, 2015, 2017a). In the AYMT, the sett sizes can be 50 g or even greater, and these larger setts have a better germination and survival rate and can even be planted directly into the field. A further refinement of the AYMT over the YMT has been the use of pesticide ‘dips’ (a mixture of insecticide and fungicide in solution) to treat the setts rather than pesticide dust/woodash applied to the surface of the setts. The dip allows for better penetration of pesticide into the sett compared with surface dusts, and this helps with control of pests, such as nematodes (Morse et al., 2009). Other approaches taken to address the issue of planting material supply are the use of stem cuttings (Asante et al., 2011), including their use within aeroponic systems (Maroya et al., 2014).

While much is known about the agronomic performance of AYMT under researcher- and farmer-managed conditions, there are still many gaps in knowledge. For example, earlier research suggested that the gender of the farmer owning the plot might play a role in the agronomic effectiveness of AYMT, with female-owned plots tending to perform less well yield-wise than male-owned plots (Morse and McNamara, 2017b). While there has been speculation on the mechanisms that may be involved, no clear conclusion has been reached to date. Similarly, how does the performance of AYMT differ between different places? Most of the results published to date from Nigeria regarding the AYMT have focussed on the Idah area, along the eastern bank of the River Niger (Morse and McNamara, 2016; Figure 1), which is understandable given that this area is a prime location for yam production, but are comparable results achieved in other places? Finally, there is still a need for more exploration of the economic performance of AYMT plots. It is known that they can be lucrative as far as gross margin goes (Morse et al., 2009; Morse and McNamara, 2016), but what are the key factors that influence this? For example, does gender of the plot owner play a role? These are the questions that form the basis for the research presented here.

<Figure 1 near here>

Methodology

Background and Location

The research was undertaken in Nigeria between 2013 and 2016 as part of a Bill and Melinda Gates Foundation (BMGF)-funded project on yams (Morse and McNamara, 2016). One component of the project focussed on the promotion of seed yam entrepreneurship in Nigeria, and this entailed the establishment and monitoring of a number of seed yam plots in each country. The monitoring was relative to agronomic and financial performance of the plots, and detailed records were kept of all inputs, including labor.

The seed yam plots that provided the data for this research were primarily located in the Idah area of Igalaland, Kogi State, and the Amoke area, Idomoland, Benue State, Nigeria (Figure 1). The choice of these locations was influenced by a number of factors. Idah is located on the eastern bank of the River Niger and sits within one of the prime ware yam-growing areas in the country, and farmers in that area tend to specialize in growing that crop. Amoke is located south of the River Benue, but further from that river than Idah is from the Niger. Amoke farmers also specialize in yam production.

The number of plots included in the research are shown in Table 2. The seed yam entrepreneurship promotion began first in Idah (2012 and 2013) before including Amoke farmers in 2014. The year 2012 was more of a test-bed for identifying and engaging with potential seed yam entrepreneurs and indeed proved to be challenging, as a severe flood of the River Niger took place that year and many plots were lost as a result. Hence this paper only focuses on the period 2013 to 2016. As can be seen from Table 2, most of the farmers owning the plots were male. The reason for this is that in Igala and Idoma culture, and indeed in much of Nigeria, yam is a male crop (Okeke et al. 2008), and men do the bulk of the work when it comes to land preparation, planting and staking. The involvement of women is mostly in marketing, but they do help with the transporting of yams during harvesting and storage. While it is not unknown for women to own yam plots, they usually pay men to do the bulk of the fieldwork.

<Table 2 near here>

Data collection

All of the plots were owned by the farmers and they were responsible for all management decisions. Plot sizes were 20 ridges of seed yam, each 20 meters long. Ridges were typically spaced at 1 meter and setts were planted along the ridges at approximately 50 cm spacing. Thus, most of the plots were 400 m^2 in area and had 800 planted setts. In 2016, the plot size was increased to 990 m^2 for Idah and 600 m^2 for Amoke. Farmers weeded the crop at least twice and staked it. Dates of planting were recorded for each site and these were transformed into days with the 1st January each year being day 1. Planting of yam setts for seed production typically takes place between April and the end of June, once the farmers have planted their main ware yam crop; the crop that provides the household with food and income.

Agronomic and financial performance data were collected from each of the plots. Sprouting counts were typically made 60 to 90 days after planting and decisions over when to harvest were made by the farmers. All tubers harvested were counted and a random sample of 50 was weighed to provide an estimate of the total weight. All of the participating farmers opted to keep their seed yams for planting rather than sell them. Hence to assess the revenue, the number of tubers harvested was multiplied by an estimated price per tuber obtained from the farmers. The estimated prices for the seed yams each year along with the sample size for the estimation are shown in Table 3. Most of the labor input came from family members and friends rather than hired hands. Hence, to calculate the cost of labor, it was necessary to impute figures based on person-hours (number of people × time taken) for each activity along with the rate for paid labor in that year. The labor rate was estimated for each year by asking the farmers and the results are shown in Table 3.

<Table 3 near here>

Data were analyzed using multiple regression via MINITAB. Dependent variables (agronomic and financial performance) were transformed by taking the natural logarithm (LN).

Model for the analysis of the agronomic data was as follows:

$$Y = \alpha + \beta 1\, AREA + \beta 2\, YEAR + \beta 3\, GEN + \beta 4\, DAY + \beta 5\, (AREA\ X\ YEAR) + \beta 6\, (AREA\ X\ GEN) + \beta 7\, (AREA\ X\ DAY) + \beta 8\, (YEAR\ X\ GEN) + \beta 9\, (YEAR\ X\ DAY) + \beta 10 (GEN\ X\ DAY) + \beta 11\, PREP + \beta 12\, PLANT + \beta 13\, WEED + \beta 14\, STAKE + \beta 15\, HARV + \beta 16\, (AREA\ X\ HARV) + \beta 17\, (YEAR\ X\ HARV) + \beta 18\, (GEN\ X\ HARV) + \epsilon$$

The dependent variables were LN germination rate, LN number of tubers/ha, LN tuber weight (kg/ha) and LN mean tuber weight (kg).

Model for the analysis of the financial data was as follows:

$$Y = \alpha + \beta 1\, AREA + \beta 2\, YEAR + \beta 3\, GEN + \beta 4\, DAY + \beta 5\, (AREA\ X\ YEAR) + \beta 6\, (AREA\ X\ GEN) + \beta 7\, (AREA\ X\ DAY) + \beta 8\, (YEAR\ X\ GEN) + \beta 9\, (YEAR\ X\ DAY) + \beta 10 (GEN\ X\ DAY) + \epsilon$$

The dependent variables were LN total cost (Naira/ha), LN revenue (Naira/ha) and LN gross margin (Naira/ha).[1]

In both models, the independent variables were:

AREA:	Area (Idah = 0; Amoke = 1)
YEAR:	2013 (0), 2014 (1), 2015 (2) and 2016 (3)
GEN:	Gender (Male = 0; Female = 1)
DAY:	Day of planting
PREP:	LN land preparation labor (person hours/ha)
PLANT:	LN Planting labor (person hours/ha)
WEED:	LN weeding labor (person hours/ha)
STAKE:	LN Staking labor (person hours/ha)
HARV:	LN Harvesting labor (person hours/ha)

Results

A table of descriptive statistics - sample sizes (N), means and standard deviations (SD) – for the data collected is provided as Table 4 (agronomic data) and Table 5 (economic data).

<Tables 4 and 5 near here>

[1] US$:Naira Official Exchange rate as of the 15th December each year: 2013 US$1= Naira 158.85; 2014 US$1= Naira 180.80; 2015 US$1 = Naira 199.00; 2016 US$1= Naira 317.00

Sprouting rate was, on average, 83%. Yields of the seed yam plots ranged between 6 and 19 t/ha, with a mean of 13.16 t/ha, 17,747 tubers/ha and a mean tuber weight of 0.73 kg (Table 4). These are good yields, probably reflecting the rich soils of the Idah and Amoke areas and the specializations of the farmers in yam production. The mean tuber weight of 0.73 kg may seem to be on the high side for seed yam tubers, but as noted in previous papers this hides a key advantage of AYMT in that farmers like the mix of seed and ware yam tubers sizes that it produces (Morse et al., 2009; Morse and McNamara, 2015).

The economic data (Table 5) suggest that mean costs were Naira (N) 915,196/ha and revenue of N 3,197,786/ha. The mean gross margin was N 2,282,591/ha, although the variation between farmers in each year can be significant and the mean coefficient of variation across the years was 33%. After conversion to US dollars (based on the official exchange rate for the 15th December each year), the corresponding figures are total costs US$4,039, revenue US$14,319 and gross margin US$10,280. This return supports the view that seed yam production via AYMT is indeed profitable (Morse et al., 2009). However, there are risks. Of the 136 plots that were established across the 4 years (2013 to 2016), 15 were lost primarily to flooding and damage from Fulani cattle; a loss rate of 11%. This is a significant risk, given the investment, although of the 121 that survived, only 3 plots made a loss. Estimated labor costs made up, on average, 60.5% of the total costs, whereas materials (largely planting material) made up, on average, 39.5% of the total cost; in both cases the standard deviation = 16.33%. However, from the farmers' perspective, the vast bulk of the cost of the plots (typically 70% or more) is in planting material, as most of the labor is provided 'free' by household members and others.

The results of the regression analyses for the agronomic variables are shown in Tables 6 (agronomic data) and 7 (economic data). Note that for the agronomic and economic analyses, the dependent variables were the natural logarithms of the raw data.

<Tables 6 and 7 near here>

There were some significant differences in agronomic variables between areas and across years. The number of tubers harvested per ha was higher in Amoke than in Idah, and across both areas, there was a significant decline in number of tubers and tuber weight between 2013 and 2016, although the pattern in this decline was different between the two areas.

The importance of planting day is highlighted in Table 6 regarding the agronomic variables. The later the planting, the lower the number of tubers harvested, weight of tubers harvested and mean tuber weight. This relationship has been noted before (Morse and McNamara, 2017b), but interestingly, in these data, there is evidence that planting date has been increasing across time. Figure 2 illustrates the trend in the mean number of tubers and tuber weight across the four years, along with the mean day of planting. The mean number of tubers and tuber weight broadly declined between 2013 and 2016, whereas the planting day tended to increase. Thus, over this period farmers, on average, planted their yam plots later in the season, although, of course, the impact of this can depend on the timing of the rains becoming established. Hence, it would seem reasonable to conclude that the decline in number of tubers and weight of harvest between 2013 and 2016 is at least in part driven by an increase in planting day.

<Figure 2 near here>

The results in Table 5 suggest that there were interactions between planting date and gender. A plot of tuber weight and mean tuber weight against planting day for male and female farmers is shown in Figure 3(A) and Figure 3(B), respectively. This trend can be explained as female farmers tended to plant their plots later than male farmers. Female farmers planted their plots, on average, at 156.7 days (SD = 18.39) when males planted their plots, on average, at 146.5 days (SD = 18.11); this difference of 10 days is statistically significant (F=9.21**; error df = 134).

<Figure 3 near here>

Similarly, the results in Table 6 suggest an interaction between area and planting day for two of the variables: weight of tubers (P=0.061) and mean tuber weight. Idah farmers tended to plant earlier than Amoke farmers. The mean planting day for Idah farmers was 145.23 (SD = 17.7) and for Amoke farmers it was 154.27 (SD = 18.82). The difference was statistically significant (F = 8.33**; error df = 134). Therefore, for the agronomic data, a major explanatory factor was planting day, although this did interact with other factors, such as gender and area.

None of the labor inputs had a statistically significant impact on the agronomic variables, although there was a significant interaction effect between harvesting labor and year and area. Indeed, the plots in Figure 3(C and D) suggest that the relationship between the logarithm of harvesting labor and the logarithm of number of tubers/ha and tuber weight/ha was curvilinear in nature. Hence, these variables increased with harvesting labor but only up to a point after which the relationship levelled off. This seems a logical relationship, and indeed would suggest that it some cases, more labor was used for harvesting than would be necessary. It should be noted that harvesting labor in the context of the records kept for these plots included the presence of women and children, who helped to park the tubers within the field before transporting them to the store. Yam is a valuable crop and it is likely that farmers would be anxious to have the crop harvested and stored as quickly as possible.

Regarding the economic data (Table 7), a pattern was less apparent than with the agronomic data. There is no evidence to suggest that the gross margin obtained by female plot owners was less than that obtained by males and the results were similar for the two areas. The dominant influence appeared to be year, along with some significant interactions between year and area, and year and gender. Variation in cost and revenue across years would be expected, given that with inflation the prices of planting material and labor vary, as indeed does the market price of seed yams.

Discussion

The dominance of planting time on the agronomic variables does stand out from this research even if the nature of this influence can vary by gender and area. Thus, it is clearly important to plant yam setts earlier in the growing season rather than later, so the plants can maximize the available water and light. It is interesting to note that across the 4 years of the plots being established, farmers tended to plant later in the season, at least up until 2016 (Figure 2). Planting time is, of course, driven in part by the onset and establishment of rains, but another factor in the case of seed yam is that farmers tend to establish their ware yam plots as a priority and only then will they turn to planting the plots for producing seed yam. It is possible that farmers have been experimenting with extending the planting date to see what would work best, given the other demands on their time, and anecdotal evidence based on discussions with some of the farmers suggests that this has indeed been the case.

While the point regarding the importance of planting date was noted in a previous paper (Morse and McNamara, 2017b), the results presented here highlight the importance of interactions between this variable and gender and area. Female-owned plots were established later than male-owned plots; showing a greater decline in yield and mean tuber weight with delay in planting time. This finding ties in with the need for women to hire men to do most of the field work with yam, and given that the men will work on their own plots first, it does mean that females will establish their own plots later in the season. Thus, while yam is a male-dominated crop, women can own yam plots, although local culture dictates that men do the bulk of the labor, especially land preparation, planting and harvesting. Women traditionally are involved more in weeding, transporting yam tubers from field to store and marketing. This male-dominated tradition extends to seed yam. While the greater involvement of females in yam production is to be welcomed, they may face the limitation of labor availability at the best time for land preparation and planting.

Planting day also interacted with area, and this was largely driven by later planting in the Amoke area relative to Idah. Idah is a more riverine area and yam planting can take place earlier because of the residual moisture. Indeed, flooding of yam plots is an issue in Idah and this comprised most of the 11% loss rate in plots across the four years. Amoke is further inland from the River Benue, although some localized flooding does occur. In both areas, seed yam plots are established after the ware yam plots and if the latter are planted later in Amoke relative to Idah, then so too will the seed yam plots.

It was not possible in these data to link labor input with the agronomic variables, except for harvesting labor. Given all of the plots were harvested by hand, it is reasonable to suppose that a link between harvesting labor and tuber number and tuber weight would exist, and it also seems reasonable to expect the two to have a curvilinear relationship. More labor would tend to generate more harvest as more effort would be placed into finding and removing the tubers from the soil, which can be quite hard and compact at the time of harvest, but this would only be so up to a point. Given that seed yam is a new crop for many of these farmers it may have been challenging for them to judge the labor required for harvest, and a concern over security is common with yam given its relatively high financial value and farmers are understandably anxious to move their tubers from field to store as quickly as possible.

The absence of any statistically significant link between independent variables, other than year and economic performance of the plots, was expected. Noteworthy here was the absence of any evidence for a difference in financial performance between male and female farmers.

Conclusions

Planting day clearly emerged as a key determinant of yield (both as number and weight of seed yam tubers) in these plots, and suggests that farmers should look to establish their seed yam plots as early as possible. However, there are trade-offs here with other on-farm and off-farm activities that farmers engage in, and this will limit the degree to which farmers can plant early in the season. Also, of course, if planting is too early, then there is a danger that the mean tuber weight will be too large and not suitable for planting as seed yams. While much of the research on seed yam production from setts has tended to focus on sett size and variety, there is a need for more research that includes planting day to see how the best seed yam weights can be achieved.

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Table 1. Adoption rates of the Yam Minisett Technique (YMT) assessed between 1991 and 2014.

Author(s)	Location of study	Adoption rate (%)	Awareness rate (%)
Onyenweaku (1991)	Imo State, Nigeria	51	
Onyenweaku and Mbubuh (1991)	Anambra State, Nigeria	51	
Chikwendu et al. (1995)	Eastern Forest Zone of Nigeria	49	
Ikeorgu and Nwokocha (2001)		< 30	
Beckford (2002)	Jamaica	3 (had tried YMT)	
Agbaje and Oyegbami (2005)		35	
Onemolease and Adisa (2005)	Oyo State, Nigeria	43.4	100
Nlerum (2006)	Rivers State, Nigeria	18.6	
Aniedu et al. (2007)	South-East Nigeria	23.2 (female); 30 (male)	
Ironkwe et al. (2007)	Abia State, Nigeria	33 (women)	58 (women)
Ironkwe et al. (2008)	Abia State, Nigeria	24 (women)	47 (women)
Tokula et al. (2008)	Kogi State, Nigeria	40 (of those aware)	95
Okoro (2008)	18 States in Nigeria	22 (of those aware)	47
Beckford (2009)	Jamaica	2 (had tried YMT)	
Matthews-Njoku et al. (2009)	Anambra State, Nigeria	71 (women, fully adopted)	
Ironkwe et al. (2009)	Enugu State, Nigeria	25	94
Nlerum (2009)	Rivers State, Nigeria	19	
Bolarinwa and Oladeji (2009)	Oyo, Osun and Kwara States, Nigeria	69	71
Ofem et al. (2011)	South Nigeria	8.57	
Wiredu et al. (2012)	Northern Ghana	41	
Akpabio et al. (2012)		36 (women)	49.6 (women)
Ajieh (2012)	Delta State, Nigeria	26 (of those aware)	46
Ayoola (2012)	Benue and Kogi States, Nigeria	9	98
Gbegeh and Akubuilo (2013)	Rivers State, Nigeria	44	
Asante et al. (2014)	Ashanti, Ghana	78	
	Brong Ahafo, Ghana	51	
Waziri et al. (2014)	Niger State, Nigeria	22	42
Lawal et al. (2014)	Niger State, Nigeria	15	33

Table 2. Number of entrepreneurs established along with the number of seed yam plots that were planted each year.

Year	Area	Number of plots established	Number of farmers		Number of sites harvested	Number of sites lost (mostly from flooding and Fulani damage)	Plot size (m^2)
			Male	Female			
2013	Idah	12	12	0	12	0	400
	Amoke	0	0	0	0	0	-
2014	Idah	20	15	5	18	2	400
	Amoke	12	6	6	12	0	400
2015	Idah	22	20	2	12	10	400
	Amoke	15	6	9	15	0	400
2016	Idah	15	9	6	15	0	990
	Amoke	40	25	15	37	3	600
Total		136	93	43	121	15	

Table 3. Estimates of the mean price (Naira) for a yam tuber and for a person hour of labor between 2013 and 2016.

		Estimated price of seed yams (Naira) †			
		2013	2014	2015	2016
Idah	Mean price (SD‡)	99.83 (24.11)	130.3 (21.61)	120.45 (21.78)	148.33 (19.97)
	Number of estimates	29	33	44	15
Amoke	Mean price (SD)	N/A	199.17 (26.1)	263.33 (22.89)	237.25 (19.61)
	Number of estimates	N/A	12	15	40

	Estimated labor rate (Naira/person hour) †			
	2013	2014	2015	2016
Idah	125	175	160	300
Amoke	N/A	140	200	300

† US$:Naira Official Exchange rate as of the 15th December each year: 2013 US$1= Naira 158.85; 2014 US$1= Naira 180.80; 2015 US$1 = Naira 199.00; 2016 US$1= Naira 317.00

‡SD = Standard deviation

Table 4. Descriptive statistics for the agronomic variables

			Sprouting rate (%)			Number of tubers/ha			Tuber weight (kg/ha)			Mean tuber weight (kg)		
Area	Year	Gender	N	Mean	SD†	N	Mean	SD	N	Mean	SD	N	Mean	SD
Idah	2013	Male	12	90.47	12.47	12	21,773	6,272	12	17,727	8,762	12	0.7993	0.2953
		Female	0	-	-	0	-	-	0	-	-	0	-	-
	2014	Male	14	93.96	4.63	14	19,145	5,559	14	16,031	7,963	14	0.8044	0.3304
		Female	4	91.65	8.48	4	20,081	1,394	4	19,132	7,808	4	0.955	0.38
	2015	Male	11	86.76	11.3	11	18,373	3,659	11	14,695	6,445	11	0.7779	0.2563
		Female	1	89.27	-	1	20,400	-	1	10,875	-	1	0.533	-
	2016	Male	9	59.69	25.06	9	12,791	5,236	9	10,253	6,311	9	0.7332	0.2672
		Female	6	59	29.8	6	12,310	6,128	6	11,767	7,162	6	0.811	0.372
Amoke	2014	Male	6	92.26	5.24	6	28,500	1,887	6	17,226	4,669	6	0.603	0.1514
		Female	6	88.29	6.74	6	26,913	2,144	6	14,446	1,925	6	0.5362	0.0532
	2015	Male	6	92.75	6.39	6	16,200	2,120	6	9,227	2,147	6	0.5835	0.1884
		Female	9	82.76	17.1	9	15,083	3,788	9	6,363	3,205	9	0.4078	0.159
	2016	Male	23	78.6	12.99	23	14,740	2,887	23	11,296	4,902	23	0.7494	0.2376
		Female	14	82.41	10.48	14	15,846	2,235	14	12,903	3,899	14	0.8049	0.1647
Mean				83			17,747			13,159			0.7251	

†SD = Standard deviation

Table 5. Descriptive statistics for the economic variables

			Total cost (N/ha) †			Revenue (N/ha) †			Gross margin (N/ha) †		
Area	Year	Gender	N	Mean	SD‡	N	Mean	SD	N	Mean	SD
Idah	2013	Male	12	696,620	190,011	12	2,173,592	626,176	12	1,476,972	557,952
		Female	0	-	-	0	-	-	0	-	-
	2014	Male	14	835,083	197,361	14	2,494,548	724,355	14	1,659,466	781,469
		Female	4	1,035,875	155,929	4	2,616,588	181,593	4	1,580,713	247,347
	2015	Male	11	737,540	131,455	11	2,212,998	440,726	11	1,475,458	502,070
		Female	1	731,750	-	1	2,457,175	-	1	1,725,425	-
	2016	Male	9	505,668	73,287	9	1,897,327	776,659	9	1,391,659	774,163
		Female	6	534,512	56,509	6	1,825,909	909,032	6	1,291,397	885,592
Amoke	2014	Male	6	1,071,040	323,246	6	5,676,342	375,848	6	4,605,302	551,444
		Female	6	1,119,840	179,732	6	5,360,163	427,021	6	4,240,323	367,654
	2015	Male	6	1,162,575	718,978	6	4,265,946	558,374	6	3,103,371	1,038,773
		Female	9	870,972	142,196	9	3,971,894	997,561	9	3,100,922	1,054,094
	2016	Male	23	1,161,764	187,515	23	3,497,033	685,049	23	2,335,269	607,143
		Female	14	1,090,125	198,828	14	3,759,569	530,358	14	2,669,444	583,941
Mean				915,196			3,197,786			2,282,591	

† US$:Naira Official Exchange rate as of the 15th December each year: 2013 US$1= Naira 158.85; 2014 US$1= Naira 180.80; 2015 US$1 = Naira 199.00; 2016 US$1= Naira 317.00

‡SD = Standard deviation

Table 6. Results of a multiple regression on the agronomic variables.

	Number of tubers/ha		Weight of tubers (kg/ha)		Mean tuber weight (kg)	
Predictor	Coefficient (SE)	t-value (sig)	Coefficient (SE)	t-value (sig.)	Coefficient (SE)	t-value (sig.
Constant	**12.43 (1.302)**	**9.54*****	**13.714 (2.339)**	**5.86*****	**1.2056 (0.521)**	**2.31***
Area	**2.725 (1.306)**	**2.09***	2.021 (2.345)	0.86 ns	-0.5483 (0.5223)	-1.05 ns
Year	**-1.5787 (0.5855)**	**-2.7****	**-2.522 (1.051)**	**-2.4***	-0.3441 (0.2342)	-1.47 ns
Gender of farmer	-0.696 (1.198)	-0.58 ns	-0.01 (2.151)	0 ns	0.4978 (0.4792)	1.04 ns
Day planted	**-0.012738 (0.00441)**	**-2.89****	**-0.032502 (0.007918)**	**-4.1*****	**-0.007334 (0.001764)**	**-4.16*****
Area X Year	**-0.5071 (0.1574)**	**-3.22****	**-0.8487 (0.2825)**	**-3****	-0.099 (0.06295)	-1.57 ns
Area X Gender	**-0.3652 (0.2019)**	**-1.81 (P=0.073)**	**-0.7983 (0.3625)**	**-2.2***	**-0.137 (0.08077)**	**-1.7 (P=0.093)**
Area X Day planted	0.005032 (0.005528)	0.91 ns	**0.018775 (0.009926)**	**1.89 (P=0.061)**	**0.005424 (0.002211)**	**2.45***
Year X Gender	**0.17 (0.1023)**	**1.66 (P=0.1)**	**0.3768 (0.1836)**	**2.05***	0.06403 (0.04091)	1.57 ns
Year X Day planted	0.002576 (0.002393)	1.08 ns	**0.007346 (0.004297)**	**1.71 (P=0.09)**	**0.0018232 (0.000957)**	**1.9 (P=0.06)**
Gender X Day planted	-0.005806 (0.004488)	-1.29 ns	**-0.017099 (0.008057)**	**-2.12***	**-0.004024 (0.001795)**	**-2.24***
LN Land preparation labor	-0.04978 (0.09092)	-0.55 ns	0.0244 (0.1632)	0.15 ns	0.0184 (0.03637)	0.51 ns
LN Planting labor	0.01031 (0.04126)	0.25 ns	-0.01204 (0.07408)	-0.16 ns	-0.00426 (0.0165)	-0.26 ns
LN Weeding labor	-0.03585 (0.05595)	-0.64 ns	-0.0681 (0.1005)	-0.68 ns	-0.00778 (0.02238)	-0.35 ns
LN Staking labor	-0.00278 (0.02928)	-0.09 ns	-0.06449 (0.05257)	-1.23 ns	**-0.02094 (0.01171)**	**-1.79 (P=0.077)**
LN Harvesting labor	-0.0744 (0.1572)	-0.47 ns	0.0883 (0.2823)	0.31 ns	0.05554 (0.06288)	0.88 ns
Area X LN Harvesting labor	**-0.3582 (0.1243)**	**-2.88****	**-0.5252 (0.2232)**	**-2.35***	-0.03527 (0.04972)	-0.71 ns
Year X LN Harvesting labor	**0.20029 (0.07403)**	**2.71****	**0.2728 (0.1329)**	**2.05***	0.02346 (0.02961)	0.79 ns
Gender X LN Harvesting labor	**0.2298 (0.1331)**	**1.73 (P=0.087)**	0.3659 (0.2389)	1.53 ns	0.01262 (0.05323)	0.24 ns
Adjusted R^2	41.2		32.3		28.3	
Standard Deviation	0.336667		0.60447		0.134663	
Error df	102		102		102	
F-value	5.66***		4.18***		3.63***	

ns = not significant at 0.05; * P<0.05 ** P<0.01 *** P<0.001. In some cases, the probability was between 0.05 and 0.1 and where this was the case, the value of P has been given.

Table 7. Results of a multiple regression on the economic variables.

Predictor	Total cost (N/ha) †		Revenue (N/ha) †		Gross margin (N/ha) †	
	Coefficient (SE)	t-value (sig.)	Coefficient (SE)	t-value (sig.)	Coefficient (SE)	t-value (sig.)
Constant	**14.1801 (0.3815)**	**37.17*** **	**14.9979 (0.584)**	**25.68*** **	**15.4366 (0.8349)**	**18.49*** **
Area	**0.8583 (0.4968)**	**1.73 (P=0.087)**	-0.7441 (0.7605)	-0.98 ns	-1.064 (1.087)	-0.98 ns
Year	**-0.5001 (0.2249)**	**-2.22***	0.4774 (0.3443)	1.39 ns	0.4827 (0.4922)	0.98 ns
Gender of farmer	0.5824 (0.4302)	1.35 ns	0.9695 (0.6586)	1.47 ns	0.7547 (0.9416)	0.8 ns
Day planted	-0.004541 (0.002878)	-1.58 ns	-0.002557 (0.004405)	-0.58 ns	**-0.007313 (0.006298)**	-1.16 ns
Area X Year	**0.22059 (0.05742)**	**3.84*** **	**-0.16039 (0.08791)**	**-1.82 (P=0.071)**	**-0.3041 (0.1257)**	**-2.42***
Area X Gender	-0.0828 (0.1149)	-0.72 ns	-0.0837 (0.176)	-0.48 ns	-0.1206 (0.2516)	-0.48 ns
Area X Day planted	-0.005552 (0.003626)	-1.53 ns	**0.01281 (0.005551)**	**2.31***	**0.016547 (0.007935)**	**2.09***
Year X Gender	**-0.16078 (0.06394)**	**-2.51***	0.04058 (0.09789)	0.41 ns	0.0789 (0.1399)	0.56 ns
Year X Day planted	**0.002898 (0.001587)**	**1.83 (P=0.071)**	-0.003746 (0.00243)	-1.54 ns	-0.003177 (0.003474)	-0.91 ns
Gender X Day planted	-0.001109 (0.002989)	-0.37 ns	-0.006371 (0.004575)	-1.39 ns	-0.005105 (0.006541)	-0.78 ns
Adjusted R^2	51		49.7		28.1	
Standard Deviation	0.239374		0.366459		0.523896	
Error df	110		110		110	
F-value	13.47***		12.84***		5.7***	

ns = not significant at 0.05; * P<0.05 ** P<0.01 *** P<0.001. In some cases, the probability was between 0.05 and 0.1, and where this was the case, the value of P has been given.

† US$:Naira Official Exchange rate as of the 15th December each year: 2013 US$1= Naira 158.85; 2014 US$1= Naira 180.80; 2015 US$1 = Naira 199.00; 2016 US$1= Naira 317.00

Figure 1. Map of Nigeria showing the location of the seed yam entrepreneur sites.

Also shown are the two major rivers in the country (Niger and Benue), the Federal capital city – Abuja – and the commercial center – Lagos.

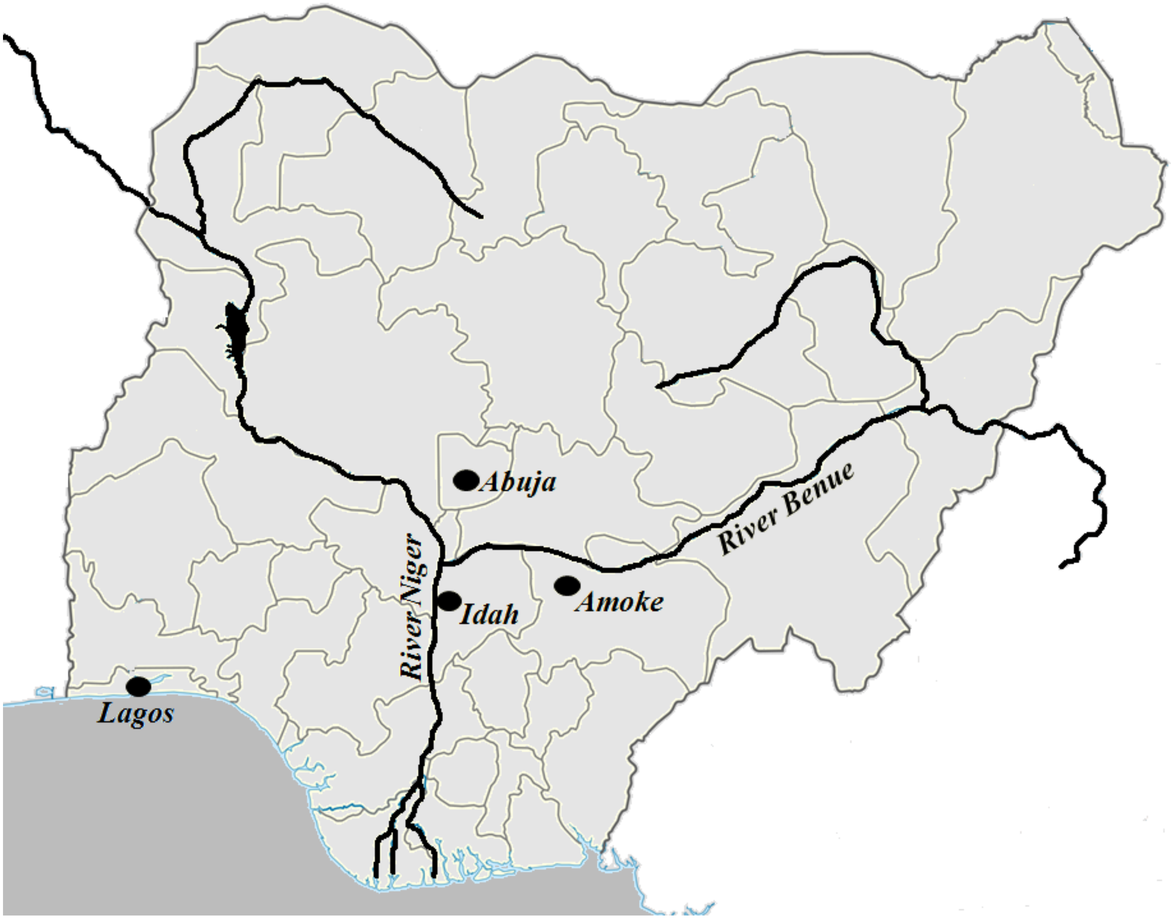

Figure 2. Trend in mean number of tubers/ha and tuber weight (kg/ha) during the period of the research (2013 to 2016), along with the day of planting.

Note: Number of tubers/ha and Tuber weight (kg/ha) expressed as natural logarithms (LN).

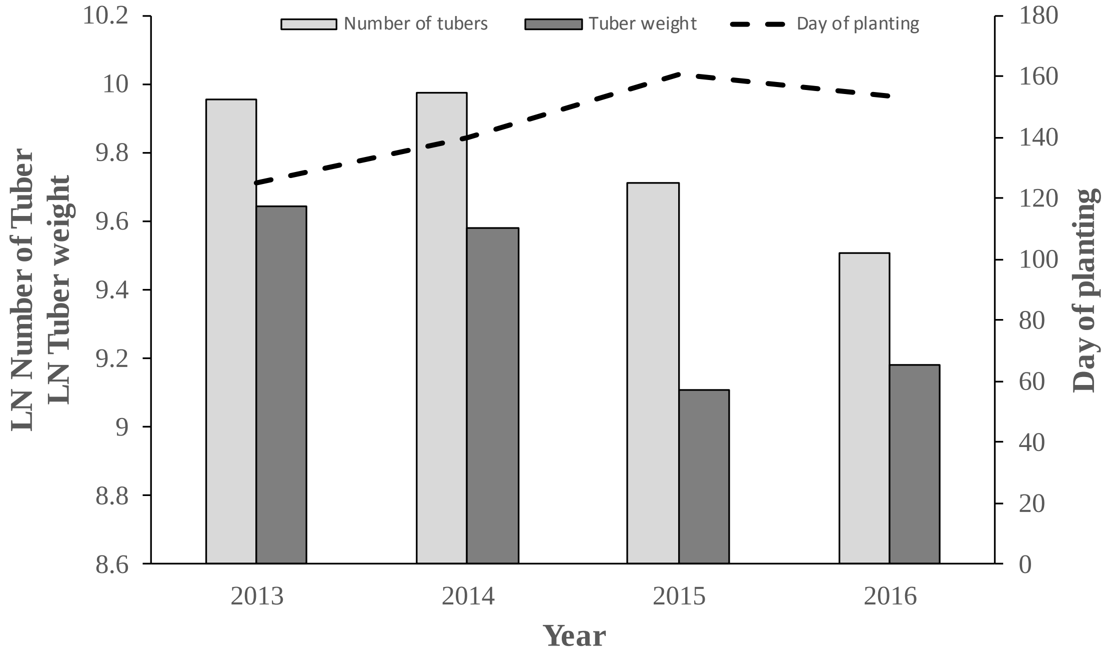

Figure 3. Graphs of some of the significant relationships shown in Tables 5 and 6.