Full Length Research Paper

Adoption of Bambara groundnut production and its effects on farmers' welfare in Northern Ghana

Adzawla William[1], Donkoh Samuel A.[1], Nyarko George[2], O'Reilly Patrick J.[3]*, Olayide Olawale E.[4], Mayes Sean[3], Feldman Aryo[3] and Azman Halimi R.[3]

[1]Faculty of Agribusiness and Communication Sciences, University for Development Studies, Tamale, Ghana.
[2]Faculty of Agriculture, University for Development Studies, Tamale, Ghana.
[3]Crops for the Future Research Centre (CFFRC), The University of Nottingham Malaysia Campus, Selangor Darul Ehsan, Malaysia.
[4]Centre for Sustainable Development, University of Ibadan, Nigeria.

With the growing concerns about the likely implications of climate change, the long term sustainability of conventional agricultural approaches and biodiversity loss have contributed to a growing interest in the potential of the so-called underutilised crops to address food, nutritional, and income security challenges. In support of their wider use, advocates of underutilised crops associate a number of benefits with them. These include agronomic and nutritional benefits such as drought tolerance and micro-nutrient content and the perceived socio-economic benefits of their wider use. It is widely suggested that the adoption of such crops can generate improved agricultural resilience and support nutrition, food and income security. Simultaneously, the adoption of underutilised crops is seen as a means of conserving biodiversity. However, scientific evidence concerning the use of such crops remains extremely limited. Crucially, little research has been undertaken concerning the contribution of such crops to the welfare of producers. This study investigates the socio-economic factors characterising the production of Bambara groundnut (*Vigna subterrana* (L.) Verdc.) in Northern Ghana and the impact of its production on farmers' welfare. Primary data was collected based on the 2013 farming season, 240 farmers were selected using a multi-stage sampling technique. A treatment effect model, comprising an adoption and a welfare model was estimated. The probability of adopting Bambara groundnut was found to be greater for: unmarried farmers; farmers in larger households; farmers with little or no formal education; and farmers who had no access to credit. The production of Bambara groundnut led to increased household welfare, as measured by the level of household per capita expenditure/consumption. Results suggest that while further research and support for Bambara groundnut production could contribute to addressing high poverty levels in the region, many of the basic assumptions underlying current advocacy of underutilised crops need rigorous empirical verification.

Key words: Adoption, underutilised crops, Bambara groundnut, Northern Ghana, treatment effect model, welfare.

INTRODUCTION

While global levels of chronic under nutrition have been on a decline since 1990, it is still estimated that a total of 805 million people (11.3%) were chronically undernourished during the period of 2012 to 2014 (FAO,

2014). Many of these people are located in the rural areas of developing nations. This raises questions as to the extent to which existing agricultural practices are capable of addressing the needs of marginalised groups in such areas. Multiple sources point to the relatively narrow range of crops upon which human food supply depends (Williams and Haq, 2002). While estimates vary, FAO (2001) suggests that less than 20 crop species constitute the main sources of human food. Equally, numerous sources suggest that the world's food supply is further concentrated with up to 60% of food supply coming from maize, rice, and wheat (Williams and Haq, 2002; Azam-Ali, 2007; Loftas and Ross, 1995). Not unsurprisingly, this has resulted in the concentration of agricultural research and development efforts on major crops leading to the further marginalization of a large number of species which have historically been cultivated in a range of different cropping systems and locations (Azam-Ali et al., 2001). This has led to their characterisation as "orphan", "indigenous", "traditional" or "neglected" crops, among other terms. While by no means universally accepted or clearly defined, the term "underutilised" is widely applied to these lesser used crops (Padulosi and Hoseschle-Zeledon, 2004; Padulosi et al., 2001). These crops are often noted as having an important role as subsistence or "famine crops" which are in many cases cultivated by small-scale farmers in tropical environments. In particular, numerous local studies have linked the cultivation of such crops with gendered agricultural systems where they are viewed as women's crops (Adu-Dapaah and Sangwan, 2004). Furthermore, specific agronomic benefits are linked to such crops, most critically that they are viewed as requiring less inputs of, for example, water, fertiliser and agrochemicals and can be grown employing local techniques with minimal external expertise. Finally, in many cases such crops are regarded as being good sources of a wide range of nutrients. Considering perceptions concerning the importance of underutilised crops to smallholder farmers in developing countries, their suitability to hostile environments, low input requirements and nutritional benefits, it is scarcely surprising that such crops have gained significant attention as a potentially important avenue for addressing global poverty and improving food security. Alongside perceptions that underutilised crops have an important role in development, such crops are also seen as an important subset of biodiversity which is threatened by modern approaches to farming, thus resulting in calls for conservation both in their own right and as a future genetic resource for agricultural growth in the future. In this context, calls for the promotion of underutilised crops are proposed as a means of simultaneously meeting development goals and supporting the "in-situ" conservation of biodiversity.

However, while the benefits of these crops have been much vaunted by their advocates, such crops continue to attract a very small portion of global research budgets. In this context, many of the claims made about these crops rely on relatively small scale studies or remain speculative. If the actual potential of such crops is to be fully understood and realised, then some consideration needs to be given to how the claims made for them bear up to empirical observation. Critically, little effort has been made to empirically assess the contribution to welfare of such crops within large populations. This study draws on empirical research to examine the impact of the adoption of an underutilised crop, Bambara groundnut, on the welfare of current cultivators.

While regularly described as underutilized, Bambara groundnut is a widely grown indigenous African legume native to Western Nigeria and Eastern Sudan (Begemann, 1988; Pasquet, 2003). While Bambara groundnut is mostly grown in the drier parts of sub Saharan Africa (SSA) it is widespread throughout tropical Africa (Brink and Belay, 2006). Historically, Bambara groundnut has been viewed as a subsistence crop and as the third most important legume crop in semi-arid Africa after groundnut and cowpea (Sellschop, 1962). Despite being the subject of very limited research and little support from agricultural or development professionals, the crop remains important in the region. Indeed, there is evidence that production has increased. In 2002, the FAO estimated worldwide Bambara groundnut production at 58,900 Mt (Azam-Ali et al., 2003) and over 100,000 Mt in 2008 (FAO, 2009). However, reflecting the general case with underutilised crops, the accuracy of estimates of Bambara groundnut production are difficult to establish due to its widespread use in subsistence farming systems for which reliable data are not collected. Other sources estimate its annual world production at about 330,000 Mts, of which 45 to 50% is produced in West Africa (PROTA, 2006; Alhassan and Egbe, 2013).

Reflecting a general trend in underutilised crop studies, limited data has not prevented significant claims being made for the crop. Within development circles and particularly in discussions of underutilised crops, the potential of Bambara groundnut is widely observed, as is the absence of large scale research concerning the crop. The State of The State of the World (SoW) (2011) made the following observation about Bambara groundnut:

"… this little bean, indigenous to tropical Africa, is highly overlooked by scientists, development agencies, and humanitarian programs, even though it packs a lot of nutrition. One reason the bean is growing in popularity is

*Corresponding author. E-mail: patrick.oreilly@cffresearch.org. Tel: +60 19 267 1062.

because it is a hardy plant, able to withstand high temperatures and dry conditions. …The Bambara bean is high in protein, particularly methionine, which makes the protein more complete than that in other beans".

Researchers have highlighted its ability to give acceptable yields on marginal soils (Hillocks et al., 2012) and under harsh environmental conditions (Azam-Ali et al., 2001). The crop's nutritional superiority has also been widely reported (Brough and Azam-Ali, 1992). Against the backdrop that Bambara groundnut does well under relatively harsh environmental and soil conditions it has been argued that cultivating the crop could make a significant contribution to alleviating the plight of small-scale farmers by provide a nutritious alternative to animal protein and providing a source of income (Hillocks et al., 2012)

In Northern Ghana, agriculture is the mainstay of the economy; however the unimodal rainfall pattern has meant that after the farming season is over, much of the region is affected by drought and people become unemployed or are compelled to migrate to the south. The high tolerance of Bambara groundnut to drought and poor soils, its benefits as a legume in a grain-dominated farming system, its market potential, as well as its nutritional advantages suggest that research and development interventions to promote its cultivation may offer possible pathways for improving the welfare of smallholder farmers in these areas. In order to establish the extent to which this is the case, this research investigated current Bambara groundnut production in Ghana with the specific objectives of (1) investigating the factors influencing the adoption of Bambara groundnut production in Northern Ghana and (2) determining the effects of adoption on farmers' welfare. This is undertaken with a view to informing the understandings of a wide range of potential stakeholders in the research and policy communities concerning how the potential of underutilised crops in development measures should be framed.

MATERIALS AND METHODS

Agronomic characteristics of Bambara groundnut

As already noted, Bambara groundnut is widely known as a hardy plant with several advantages including: high tolerance to drought; ability to yield on lands that are not fertile enough for the cultivation of many other crops; and good nutritional characteristics (Azam-Ali et al., 2001; Bamshaiye et al., 2011). As a leguminous crop, Bambara groundnut's fertilizer requirements are also low as compared to many other crops (Linnemann, 1990). The crop can grow well under an average temperature of 20 to 28°C, an annual mean rainfall of 500 to 600 mm and a soil pH of 5.0 to 6.5. Furthermore, Bambara groundnut is seen as being valuable in intercropping and crop rotation systems due to its nitrogen fixing ability. However, as an underutilised crop which has not been the subject of widespread formal breeding endeavour, it exists as a large number of landraces rather than varieties (Redjeki et al., 2011). The germplasm of the crop is characterised by significant genetic

variability, reflected in considerable morphological and agronomic differences. This is evident in the wide range of colouration in the seed produced by different landraces varying from black, red, and brown, to cream/black eye, cream/brown eye, cream/no eye, and speckled/flecked/spotted patterning, as well as an average seed weight ranging between 280 and 320 g (Ojimelukwe and Ayernor, 1992). Lacroix et al. (2003) noted that the lack of genetic improvement alongside other issues arising from the lack of attention the plant has received, such as, inadequate knowledge on the taxonomy; reproductive biology, agronomic, and quality traits have obstructed the Bambara groundnut's wider adoption. Also, in the case of its utilisation, the lack of adequate processing techniques to address problems related to long cooking time hinders the crops wider use.

Study area

The study was carried out in the three northern regions of Ghana, namely; the Northern, Upper East and Upper West regions. Agriculture is the mainstay of the people in Northern Ghana. Major staple crops cultivated include maize, millet, yam, sorghum, rice, groundnut and cowpea as well as Bambara groundnut (Quaye, 2008). Farm activities in the region are challenged by erratic rainfall (drought), flood and in some instances, bushfires and declining soil fertility. Poverty in the north of Ghana is also more pronounced than in the south, with the former also having less infrastructural facilities (GSS, 2014). The cultivation of Bambara groundnut is more common in these regions than in the southern regions of Ghana perhaps reflecting its ability to thrive in marginal and drought affected areas.

Sampling, data collection and procedure

The study involved 240 respondents, 120 Bambara groundnut farmers and 120 non Bambara groundnut producers. The sample was selected through a multi-stage procedure. In the first stage, two districts from each of the three northern regions were randomly selected. Also by a simple random approach, two communities were then selected from each district making a total of four communities in each region. In the second stage, the farmers in each community were put into two strata: (1) Bambara groundnut farmers and (2) non-Bambara groundnut farmers. And then, 10 respondents from each of the stratum were selected from each community by simple random sampling. This allowed for 40 Bambara groundnut farmers and 40 non Bambara groundnut farmers to be selected in each region.

A semi-structured questionnaire was used in gathering the relevant data for the study. Data was collected on the socioeconomic characteristics of the farmers as well as the welfare status of his/her household. Thirteen key components were considered as indicators of household welfare. These included the annual household total expenditure on food, accommodation, clothing, education, health, utility, transportation, ceremonies, entertainment, communication, fuel, savings, maintenance of assets and others. These were aggregated and divided by the household size in line with the methods used by the Ghana Statistical Service (GSS, 2008) to give household per capita expenditure. Thus in this research, welfare is equivalent to household per capita expenditure or household per capita consumption. It is acknowledged that this is a limited definition of welfare since it does not take into account other elements of welfare such as quality of food, the environment, health status or happiness. However, taking into account the resource constraints under which the survey was conducted, the use of this approach serves as a preliminarily measure which is related to these other

indicators of welfare.

Data analysis

In order to address the questions of adoption and contribution to welfare, two equations were estimated: one for the determinants of farmers' adoption of Bambara groundnut production and the other on the effects of Bambara groundnut production on welfare. In the case of the first equation, a limited dependent model such as the probit model is appropriate since the dependent variable in this case is binary: 1 if a household has adopted the cultivation of Bambara groundnut and 0, otherwise. On the other hand, the welfare equation can be estimated using a linear estimator, such as the ordinary least squares (OLS). However, to correct for a possible sample selection bias, we estimated a treatment effect model which adapts Heckman's two stage estimation for the correction of sample selection bias. In the sections that follow, an explanation of the probit model was offered as well as the steps involved in overcoming the problem of selectivity bias.

Probit model

The probit model is one of the specialized regression models of binomial response variables. For instance, the question asked in this study was, what is the relationship between households' adoption or non-adoption of Bambara groundnut production and their socio-economic characteristics? The implication is that during the farming season in question, some households cultivated Bambara groundnut while others did not. This meant that there were only two sets of respondents, Bambara groundnut producers and non-producers, leading to a dichotomous treatment variable. The probit model (or its logit equivalence) allows for estimating these 'choice' situations. The purpose of the model is to estimate the probability that an observation with a particular characteristic would fall into one specific category.
Mathematically,

$$y_i = \beta' x_i + u_i \tag{1}$$

where y_i is a binary response variable. Stating the underlying response variable y^*

$$y_i^* = \beta' x_i + u_i \tag{2}$$

where x_i is a vector of random variables that influences y_i and β_i is a vector of parameters to be estimated. In practice, y^* is not observed and instead a dummy variable was observed and defined as:

$$y = 1 \; if \; y_i^* > 0 \; \text{or} \; y = 0 \; \text{if otherwise} \tag{3}$$

The respective probabilities are $-\beta' x_i$ and $1 - \beta' x_i$. In this case, $\beta' x_i$ is no longer $E(y_i/x_i)$ as in OLS but $E(y_i^*/x_i)$. From Equations 2 and 3,

$$Prob(y = 1) = Prob(u_i > -\beta' x_i) \quad = 1 - F(-\beta' x_i) \tag{4}$$

where F is the cumulative distribution function of u_i. Depending on

x_i, the probabilities given in Equation 4 may vary, hence the likelihood function is:

$$L = \prod_{y_i=0} F(-\beta' x_i) \prod_{y_i=1} [1 - F(-\beta' x_i)] \tag{5}$$

Since the probit model assumes that u_i is normally distributed $[N(0, \sigma^2)]$,

$$F(-\beta' x_i) = \int_{-\infty}^{-\beta' x_i/\sigma} \frac{1}{(2\pi)^{1/2}} exp\left(\frac{-t^2}{2}\right) dt \tag{6}$$

From Equations 5 and 6, the expression $\beta' x_i / \sigma$ can be estimated as opposed to either β_s or σ. In predicting the effects of changes in the jth element of the x_i belonging to a group (that is, marginal effects), the following formulation can be used:

$$\frac{\partial}{\partial x_{ij}} \Phi(x'\beta) = \emptyset(x'\beta)\beta_j \tag{7}$$

Selectivity bias and the treatment effect model

In practice, sample selection bias may arise for two reasons. First, one can observe welfare values for Bambara groundnut producers and not for non-Bambara groundnut producers. Similarly, there can be observable welfare values for both Bambara groundnut producers and non-producers, but the selection of the respondents by the researcher in both categories may follow a discretionary pattern and not by random; as is the case in this research. This means that Bambara groundnut producers may have unmeasured characteristics that are related to their welfare. If Bambara groundnut adoption is put into the substantive equation (welfare function) as an explanatory variable, the parameter estimates would be biased, and this would mean that the true effect of adoption on welfare would not be known (Heckman, 1976). In other words, Bambara groundnut producers may be different from their non-producing counterparts in many ways and if these characteristics of the producers are related with their welfare level, then the effect of Bambara groundnut production on welfare would be overestimated. To explain further, assuming after estimation of the welfare equation, it was found out that the welfare levels of Bambara groundnut producers, on a whole are higher than non-Bambara groundnut producers, what shows that it is Bambara groundnut production that has made the former richer and not the fact that they are intrinsically more hardworking than the latter? Heckman (1979) suggested several but similar ways in which the problem could be corrected depending on the relationship being examined. One of such model is the treatment effect model.

The treatment effect model is a special case of Heckman's two stage estimation procedure where the dependent variable of the selection equation is an additional explanatory variable in the substantive equation. Maddala (1983) and Greene (2003) have given a comprehensive theoretical explanation of the causes and treatment of the selectivity bias problem.
Following Greene (2003), Equation 1 may be re-written as:

$$A_i^* = z_i' \gamma + e_{1i} \quad \text{(Selection equation)} \tag{8}$$

where $A_i = 1$ if $A_i^* > 0$ the *ith* farmer has adopted Bambara groundnut production and zero if otherwise. Z is a vector of farm and household characteristics; and A_i is the observed value of the latent variable, adoption. e_{1i} is a two-sided error term with $N(0, \sigma_v^2)$.
Also let,

$$W_i = z_i\beta + A_i\delta + e_{2i} \quad \text{(Substantive equation)} \qquad (9)$$

where W_i is welfare; e_{2i} is also a two-sided error term with $N(0, \sigma_v^2)$. β and δ are parameters to be estimated.

According to Heckman (1979), estimating Equation 9 with the observed values of adoption, A will result in biased estimates, and instead, he suggested that the selection Equation 8 should first be estimated so that the predicted values of A are used. Also, an Inverse Mills Ratio (IMR) should be formed using the predicted values of A as an additional regressor in the substantive equation. This is because the decision to adopt may be influenced by unobservable variables like management ability that may also influence welfare. This implies that the two error terms e_{1i} and e_{2i} in the selection and substantive equations respectively are correlated, leading to biased estimates of β and δ.

If we assume that e_{1i} and e_{2i} have a joint normal distribution with the form:

$$\begin{bmatrix} e_{1i} \\ e_{2i} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 1 & \rho \\ \rho & \sigma^2 \end{bmatrix} \right),$$

$$(10)$$

Then it follows that the expected welfare of those who adopt Bambara groundnut production is given as:

$$E[W_i \mid A_i = 1] = z_i\beta + \delta + E[e_{2i} \mid A_i = 1]$$
$$= z_i\beta + \delta + \rho\sigma\lambda_i$$

$$(11)$$

where $\lambda_i = \dfrac{\phi(-z_i'\gamma)}{1 - \Phi(-z_i'\gamma)}$ is the IMR. $\qquad (12)$

ϕ and Φ are the standard normal and the cumulative density functions respectively. Equation 12 implies that if we estimate Equation 9 without the IMR, the coefficients β and δ will be biased, which justifies the use of Heckman's two-stage procedure. According to Maddala (1983), if we use all observations on welfare for both categories of farmers, Equation 9 takes the form:

$$W_i = \beta'(\Phi_i z_i) + \delta'(\Phi_i A_i) + \sigma\phi_i + e_{2i} \qquad (13)$$

where $\quad \Phi_i \equiv \Phi(z_i'\gamma)$

Empirical models

Following the aforementioned theoretical model, the empirical model to investigate the factors that influence the adoption of Bambara groundnut production and its effects on households' welfare is as follows:

$Adoption =$
$\beta_0 + \beta_1 Marital\ status + \beta_2 Household\ size + \beta_3 Education + \beta_4 Land\ ownership +$
$\beta_5 Group\ membership + \beta_6 Extension\ visit + \beta_7 Credit\ access +$
$\beta_8 Rainfall\ requirement + \beta_9 Maturity + u_i$

$$(14)$$

$Welfare = \omega_0 + \omega_1 Household\ size + \omega_2 Education + \omega_3 Land\ ownership + \omega_4 Off-$
$farm\ activity + \omega_5 Credit\ acces + \omega_6 Adoption + \varepsilon_i$

$$(15)$$

Description of variables

Table 1 shows the variables included in the models, their units of measurements and expected effects on Bambara groundnut adoption and farmers' welfare.

RESULTS AND DISCUSSION

This section presents the results and discussion of the maximum likelihood estimation of the treatment effect model. The specific equations estimated are the adoption and welfare equations (Equations 14 and 15). It begins with descriptive statistics of the variables used in the estimation as well as the reasons for cultivating or not cultivating Bambara groundnut.

Descriptive statistics of variables

Table 2 shows the descriptive statistics of the variables used in the study. Thus the average Bambara groundnut producer is 40.3 years old and the non-producer is 38.8 years old. Education is generally low among the entire set of sampled farmers. The average farmer attended school up to lower primary level (not more than 3 years of formal education). Non-producers had one year of education more than the producers ((3.4) compared to 2.4 years). The average household size was 10. There were about two more people in the producers' households (10.9) than in the non-producers' households (9.4). The average number of years a farmer had been a member of a farmer group was low considering a mean of 1.4 years. This may be of significance since membership of a farmer group is sometimes a prerequisite for accessing credit. The respective figures for Bambara groundnut producers and non-producers were 1.3 and 1.5 years. On the average, Bambara groundnut producers had a higher number of extension contacts (2.3) than the non-producers (1.9).

Reasons for Bambara groundnut cultivation

Despite the characterization of underutilized crops as subsistence crops, Figure 1 shows that more than half of

Table 1. Definition of variables.

Variable	Measurement	A priori expectation	
		Adoption	Welfare
Adoption	Dummy; 1 if a farmer is a Bambara groundnut farmer and 0 if a non- Bambara groundnut farmer	NA	NA
Welfare	Household per capita expenditure per year.	NA	NA
Marital status	Dummy; 1 if a farmer is married and 0 if single.	+	NA
Education	Total number of years of a farmer's formal education.	-/+	+
Household size	Number of people in a farmer's household cooking from the same pot.	+	-
Land ownership	Dummy; 1 if farmer owns land and 0 if Rented/family/community land	+	+
Off-farm	Dummy; 1 if a farmer does not engage in off-farm activity and 0 if otherwise.	NA	-
Farmer group membership	Total number of years of group membership.	+	NA
Extension	Number of times a farmer had contact with an extension officer.	+	NA
Credit	Dummy; 1 if a farmer accessed credit and 0 otherwise	+	+
Perception of rainfall requirement	Dummy; 1 if the farmer perceives that Bambara groundnut cultivation requires little rainfall, 0 if Bambara groundnut cultivation is perceived to require much rainfall	+	NA
Perception about time of maturity	Dummy;1 if Bambara groundnut is perceived to mature earlier than other legumes and 0 if otherwise	+	NA

Table 2. Descriptive statistics of variables.

Variable	Bambara groundnut-Producers			Non-Bambara groundnut Producers			Pooled		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Age	19	75	40.3	19	70	38.8	2	75	39.5
Education	0	16	2.4	0	12	3.4	0	16	2.9
Household size	3	27	10.9	2	29	9.4	2	29	10.1
Farmer group membership	0	10	1.3	0	12	1.5	0	12	1.4
Extension	0	12	2.3	0	12	1.9	0	12	2.1

the farmers (53.3%) cultivated Bambara groundnut for both subsistence and for cash while 38.4% cultivated it solely for home consumption. A small number (7.5%) cultivated it solely for cash and 0.8% stated that they did so for social reasons such as funerals or having inherited the culture of cultivation from their families.

Reasons for non-cultivation of Bambara groundnut

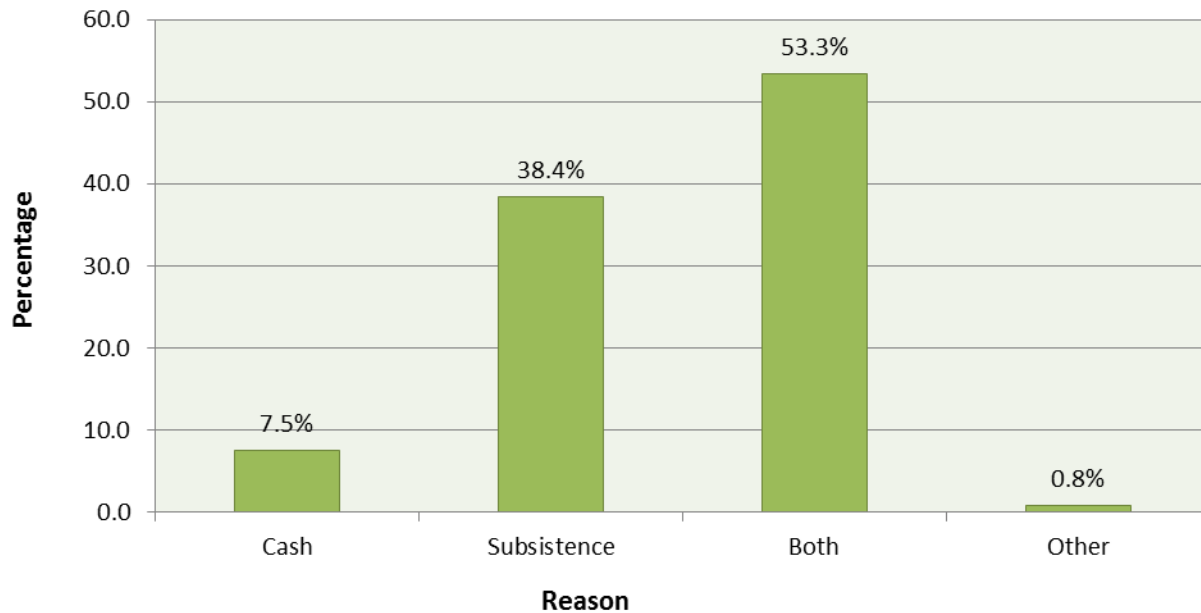The reasons cited for choosing not to cultivate Bambara

Figure 1. Reasons for cultivating Bambara groundnut.

groundnut in place of other competing crops are outlined as follows. These reasons provided justification for a continual marginalisation of the crop.

Difficult to cultivate (53.6%): Respondents indicated they considered the crop difficult to cultivate and harvesting is also very tedious, as compared to the other legumes.

Unavailability of enough land to cultivate the crop (33.2%): Some farmers indicated that they had used up all their nearby lands for the cultivation of other crops, and they were not prepared to travel far distances to cultivate Bambara groundnut.

Some farmers (36.1%) stated that they simply did not have the time to add Bambara groundnut to their existing cultivation. The farmers intimated that they are much into the cultivation of staple crops such as maize and cowpea, hence could not add Bambara groundnut to their production list.

No extra capital (42.4%): Some farmers also intimated that lack of extra capital was the reason they did not go into the production of Bambara groundnut.

Comparing Bambara groundnut to other legumes, some respondents (25.9%) stated that the other legumes like groundnut and cowpea produced higher yields than Bambara groundnut, hence they preferred cultivating those other legumes to Bambara groundnut.

Low demand by household members (27.2%). The demand for the crop in some households was so low that they did not see a need to cultivate it.

Nevertheless, 77.5% of the non-producers indicated that they would be willing to go into the production of the crop. This suggests that if supported, there is a potential to increase the current level of production of the crop.

Factors influencing the adoption of Bambara groundnut production

As indicated earlier, the first objective of this current study was to investigate the factors that influence farmers' adoption of Bambara groundnut production. From the results presented in Table 3, the factors that had a significant positive effect on the adoption of Bambara groundnut production were household size and extension services. Marital status, education and credit on the other hand had a negative influence on the adoption of Bambara groundnut production. The rest of the variables were not significant.

The implication of the positive marginal effect of household size is that farmers with larger households tended to cultivate Bambara groundnut more than those with fewer household members. This may indicate that in farming communities where household members are an important source of farm labour, Bambara groundnut cultivation could be linked to labour availability. This finding is consistent with that of Deressa et al. (2008).

Another equally important issue that is of relevance is the impact of extension visits. The positive significant marginal effect of this variable in the analysis suggests that extension staff have a positive impact on the cultivation of Bambara groundnut. As indicated earlier, farmers in the study area are more inclined to cultivate staple crops, such as maize, rice and millet. Somewhat counter to our *a priori* expectation, Bambara groundnut producers received extension visits 2.3 times during the farming season under review, as opposed to 1.9 times by non-producers. Deressa et al. (2008) also found similar effect of extension contact on the adoption of new crop

Table 3. Maximum likelihood estimates of the determinants of adoption of Bambara groundnut   production.

Variable	Marginal effect	Standard error	Z-Value	P>Z
Constant	0.145	0.338	0.43	0.668
Marital status	-0.520 **	0.244	-2.13	0.033
Household size	0.034 *	0.019	1.81	0.071
Education	-0.0366 *	0.022	-1.67	0.095
Land ownership	-0.053	0.182	-0.29	0.769
Group membership	0.219	0.158	1.39	0.166
Extension visit	0.304 *	0.156	1.95	0.051
Credit	-0.536 **	0.242	-2.21	0.027
Rainfall requirement	0.030	0.155	0.20	0.845
Maturity	-0.152	0.139	-1.10	0.272
Chi sq.	11.96 ***	-	-	0.000

***, **, and * are significant levels at 1, 5 and 10%, respectively.

varieties.

In most farming communities, increased formal education is generally associated with people abandoning agriculture in favour of better paid off-farm employment. Ibekwe et al. (2010) indicated that as farm households' education increases, they tend to pursue non-agriculture occupations. This is because education improves their human capital and therefore becomes more skillful, risk prone and able to meet current demand for economic growth. However, in their case, Uematsu and Mishra (2010) argued that although higher formal education is associated with off-farm employment opportunities, farmers with higher education may also realize higher productivity in on-farm ventures. In addition, amongst those whose main occupation is agriculture, the better educated tend to favour established commercial crops over underutilised or "indigenous" crops such as Bambara groundnut. Schultz (1975) therefore noted that formal education has a much stronger effect in modernised agriculture than in traditional agriculture. It is not surprising therefore that in this current study, the probability of adopting Bambara groundnut production was inversely linked to the extent of farmers' formal education. While farmers who cultivate the crop demonstrated an awareness of its benefits, there is no evidence that growers have an awareness of the benefits linked with the crop in scientific or policy literature. From an *a priori* perspective it might be assumed that better educated farmers are those more likely to respond positively to new information concerning the environmental adaptive capacity of alternative crops such as Bambara groundnut and thus more likely to adopt it should a convincing case be made for it. The fact that there is no such link in relation to Bambara cultivation in this study suggests that there has been little attempt to present the benefits of the crop to farmers.

From the literature, Bambara groundnut is believed to be a crop which requires only limited external inputs. This means that less money and resources are required to cultivate the crop when compared with other crops. Bambara groundnut production is also regarded as subsistence rather than a cash crop. This suggests that farmers are less likely to borrow to finance its production. The research appears to reflect this with an estimated negative marginal effect of credit being observed. It may be the case that those farmers who do have access to credit tend to use it to cultivate major commercial crops or staples which require higher levels of inputs. In the event that Bambara groundnut cultivation is up scaled to a commercial level, it is likely that credit will definitely play a more important role. However, as things stand, Bambara groundnut appears to be the choice of those with poor access to credit.

Determinants of Welfare

The second and key objective of the study was to estimate the welfare implications of the adoption of Bambara groundnut production. The study found that the cultivation of Bambara groundnut had a significant positive effect on the welfare of the farmers (Table 4). Other factors that were significant in determining welfare were household size, off-farm job participation and credit. However, while the coefficient of household size was negative, those of off-farm employment and credit were positive. Also, the significance of lambda in the model suggests that selectivity bias was present and therefore the estimation of a treatment effect model within the context of Heckman's (1979) two stage procedure for correcting selectivity bias was appropriate. The estimated coefficients were, thus, freed from biasedness and therefore measured the true effect of adoption on welfare. The positive adoption coefficient meant that in general, Bambara groundnut farmers had greater welfare (that is, per capita consumption) than non-Bambara groundnut farmers. This is a very important finding which justifies, at the very least, support for increased research concerning

Table 4. Maximum likelihood estimates of the determinants of welfare.

Variable	Coefficient	Standard error	Z-Value	P>Z
Constant	819.782	132.458	6.19	0.000
Household size	-57.046 ***	9.788	-5.83	0.000
Education	12.562	11.164	1.13	0.261
Land ownership	-89.571	95.253	-0.94	0.347
Off-farm	120.038 *	71.820	1.67	0.095
Credit	253.438 **	122.154	2.07	0.038
Adoption	875.782 ***	131.339	6.67	0.000
Lambda	-500.187 ***	76.670	-	0.000

***, **, and * are significant levels at 1, 5 and 10%, respectively.
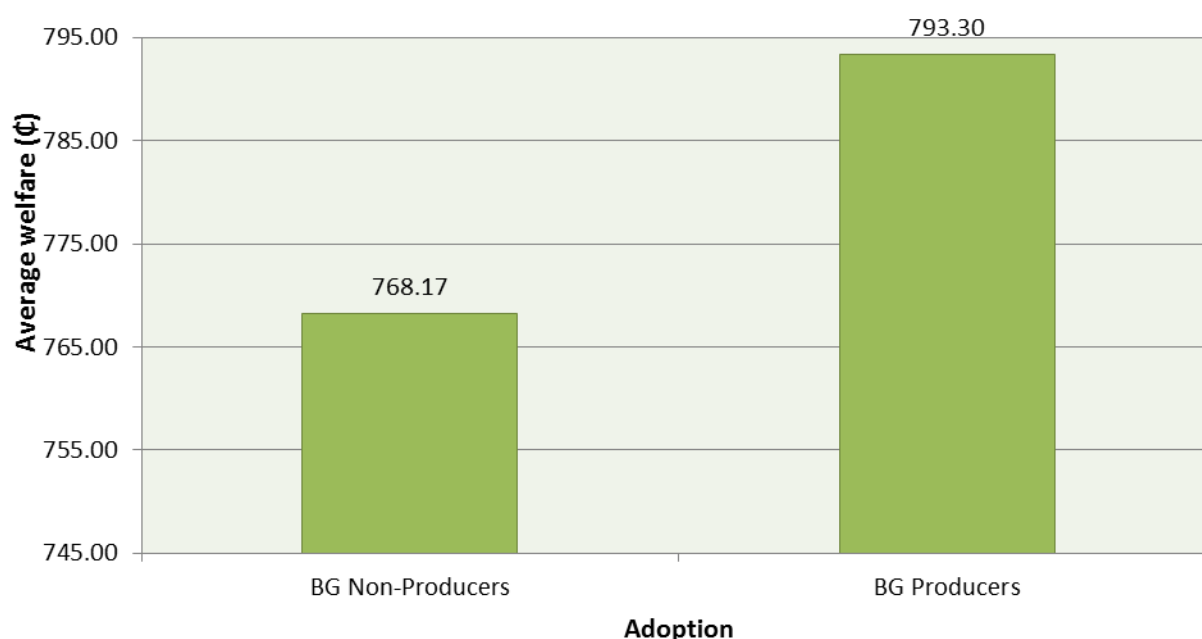
Figure 2. Adoption and average welfare.

the production of Bambara groundnut in the study area as well as into its welfare impacts. Figure 2 below confirms the estimated positive effect of adoption on welfare. On the average, Bambara groundnut producers had higher welfare (GH₵793.30 equivalent to $230.00) than the non-Bambara groundnut producers (GH₵768.17 equivalent to $220.00) it should however be noted that the overall level of this improvement was small and was not consistent across all three regions.

From Figure 3, it can be observed that among the producers, the highest level of welfare was recorded in the Northern region (GH₵879.24), followed by the Upper East (GH₵800.63) and Upper West (GH₵709.83). However, among the non-producers, while the highest level of welfare is still recorded in the Northern region (GH₵822.05), the Upper West region comes second

(GH₵769.89) followed by the Upper East region (GH₵712.58). In Ghana, Upper West region is the poorest followed by Northern region and Upper East region (GSS, 2014)

Credit is an important aspect of household asset-building, and serves as an important production resource. The result indicated that those farmers who had access to credit in the 2013 production season had improved welfare as opposed to those who had no credit. With credit, farmers are able to acquire inputs which help to raise their productivity. However, it must be recalled that credit had a negative effect on the adoption of Bambara groundnut production. Thus, although farmers who had access to production credit were not likely to go into Bambara groundnut production, those who accessed it had higher welfare. An interesting question therefore is
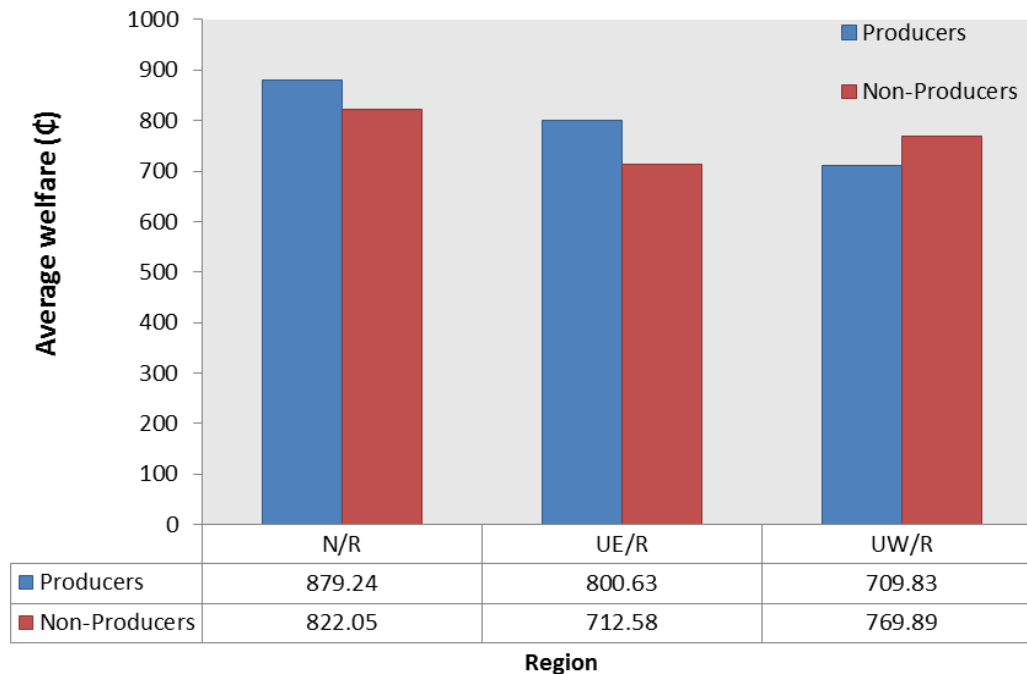
Figure 3. Welfare by region.

the extent to which the cultivation of Bambara groundnut can deliver increases in welfare when compared to welfare gains achieved through improving access to credit.

The negative coefficient of household size means that the larger a farmer's household, the smaller their welfare. This may be attributed to the fact that more household members put more pressure on household resources and the distribution of these resources among the individual members. This meets the *a priori* expectation and also confirms the findings by Donkoh *et al.* (2014). It is important to recall that household size had a positive impact on adoption. This means that although larger household augers well for Bambara groundnut production, it reduces farmers' welfare. In this context, it may be worth further examining the capacity of Bambara groundnut cultivation to play a role in mitigating the adverse impact of household size on the welfare of farming households.

The effect of off-farm participation also contradicted our *a priori* expectations. Considering the unimodal rainfall pattern of the area, one would expect that those with off-farm engagements would have higher welfare than those without. The opposite was found to be the case in this study; farmers who did not participate in off-farm activities had higher welfare. Possible explanations included the possibility that off-farm engagements fail to match the benefits that can be derived from full time farming; or that off farm employment is used as a coping strategy by those who do not have the capacity to generate an adequate livelihood from farming.

CONCLUSIONS AND RECOMMENDATIONS

Its regular description as an underutilised crop has resulted in the Bambara groundnut's depiction as a subsistence crop, often associated with women and used in intercropping systems. While such views are consistent with ideas about underutilised crops which are generally in circulation, the extent to which these ideas have been born out in empirical research is limited. By their very nature these crops have received very little research attention, furthermore, their status means that they often fail to feature in national statistics. However lack of visibility in national data sets needs not necessarily equate to lack of importance or lack of potential. It does however point to the need for a greater research effort concerning the role of such crops in current agricultural settings and a more informed discussion of their impact on welfare. The study sought to initiate such efforts by investigating the factors that influence the adoption of Bambara groundnut production and its effects on farmers' welfare in Northern Ghana. The method of analysis involved an estimation of a treatment effect model to correct for a possible sample selection bias. While some of the findings support the ideas often associated with underutilised crops in general and Bambara groundnut production in particular, such as the negative impact of levels of education and access to credit on Bambara cultivation, others contradicted them. At the very least, the study suggests that the picture of the crop's use and value in relation to smallholding in northern Ghana is more complex than the characterization of underutilised

crops suggests. This raises questions concerning whether and in what circumstances the promotion of underutilised crops can be an effective means of improving the welfare of smallholder farmers.

The study revealed that Bambara groundnut is indeed a marginalised crop in the sense that farmers were more inclined to produce staple crops (e.g. maize, rice and millet) and what they perceived to be more important cash crops (e.g. groundnuts and cowpea) (see reasons for non-cultivation of Bambara groundnut). On the whole, however, Bambara groundnut producers had greater welfare (measured as per capita consumption) than non-producers. The study also demonstrated that Bambara groundnut is employed by small farmers living in marginal agricultural areas in ways which are consistent with the use of other crops. Distinctions between the production of crops for cash and subsistence are not clear and surpluses are made available for sale after household needs are met. Findings in relation to the positive link between extension visits and Bambara groundnut production and between single farmers and Bambara groundnut production also highlight the need for further research into the mechanisms and motivations which prompt farmers to grow a supposedly marginalised crop. However, perhaps the key finding of the study is that Bambara groundnut farmers had increased welfare compared to that of non-producers. What makes this finding particularly compelling is that this was the case for farm households who otherwise lacked the characteristics associated with higher levels of welfare such as access to credit and smaller family size. Thus, the study raises the possibility that the development of programmes for underutilised crops may provide a useful alternative pathway through which to improve the welfare of smallholder households. Simultaneously however, it suggests that there are other circumstances under which it is unlikely that farm household welfare will be improved through the adoption of such crops. In this context it is perhaps notable that the question of assessing the overall impact of underutilised crop production on producing households welfare and indeed of identifying the circumstances under which this can yield better outcomes than alternative development strategies has not received sufficient attention in the literature concerning underutilised crops. This has generally promoted their use in marginal contexts without exploring the dynamics of their current use or exploring how and in what circumstances their positive impact on welfare may be of greater impact than alternative development strategies. At the very least, this study thus illustrates the need for further research concerning the circumstances under which farmers can benefit from the wider cultivation of underutilised crops. Or the means through which this can be transmitted to wider farmer networks is by extension workers.

More generally however, the study raises an important issue concerning the need to incorporate research which examines how programmes to promote underutilised crops can benefit smallholder welfare at an early stage in the design and implementation projects related to these crops. Policy makers and researchers also need to further examine questions concerning the merits of supporting the cultivation of Bambara groundnut. The perception that the crop involves extra labour raises critical questions as to the circumstances under which the crop's contribution to household welfare justifies its cultivation and as to whether research and development concerning the crop should aim to reduce labour requirements or deliver a sufficient premium to growers to cultivate it and indeed to identifying the circumstances under which this represents a viable development pathway. Similarly, given the status as an underutilised crop, the extent and mechanism through which extension impacts on the adoption of Bambara groundnut requires further exploration.

Conflict of interests

The authors have not declared any conflict of interests.

REFERENCES

Adu-Dapaah HK, Sangwan RS (2004). Improving Bambara groundnut productivity using gamma irradiation and in vitro techniques. Afr. J. Biotechnol. 3(5):260-265.

Alhassan GA, Egbe MO (2013). Participatory Rural Appraisal of Bambara groundnut (*Vigna subterranea* (L.) *Verdc.)* Production in Southern Guinea Savannah of Nigeria. J. Agric. Sci. 1:18-31.

Azam-Ali S (2007). Agricultural diversification: the potential for underutilized crops in Africa's changing climate. Riv. Biol. 100(1):27-37.

Azam-Ali SN, Massawe FJ, Mwale SS, Basu S, Cornelissen R (2003). Can Bambara groundnut become a major World Crop? Proceedings of the International Bambara groundnut Symposium, Botswana College of Agriculture, Botswana. pp. 323-336.

Azam-Ali SN, Sesay A, Karikari SK, Massawe FJ, Aguilar-Manjarrez J, Brennan M, Hampson KJ (2001). Assessing the potential of an underutilized crop – a case study using Bambara groundnut . Exp. Agric. 37:433-472.

Bamshaiye OM, Adegbola JA, Bamishaiye EI (2011). Bambara groundnut : an Under-Utilized Nut in Africa. Adv. Agric. Biotechnol. J. 1:60-72.

Begemann F (1988). Bambara groundnut (*Vigna subterranea*, (L.) Verdc.): Pests and Diseases. International Institute of Tropical Agriculture (IITA), Genetic Resources Unit, Ibadan, Nigeria. 18 pp.

Brink M, Beley G (2006). Plant resources of tropical Africa 1: cereals and pulses. PROTA Foundation, Wageningen, Netherlands/Backhuys Publications, Leiden, Netherlands/CTA.

Brough SH, Azam-Ali SN (1992). The effect of soil moisture on the proximate composition of Bambara groundnut (*Vigna subterannea* (L) Verdc.). J. Sci. Food Agric. 60:197-203.

Deressa T, Hassan RM, Alemu A, Yesuf M, Ringler C (2008). Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia IFPRI Discussion Paper, September 2008.

Donkoh SA, Alhassan H, Nkegbe PK (2014). Food expenditure and household welfare in Ghana. Afr. J. Food Sci. 8(3):164-175.

FAO (2001). Food and Agriculture Organization of the United Nations. Agricultural Information Management Series: A Global Mapping System for Bambara groundnut Production. Rome.

FAO (2014). WFP. The State of Food Insecurity in the World 2014 strengthening the enabling environment for food security and

nutrition. FAO, Rome, Italy.

FAO (2009). Food and Agriculture Organization. FAOStat. Food and Agriculture Organisation of the United Nations, Rome, Italy. Available at: http://faostat.fao.org/default.aspx

Greene WH (2003). Econometric Analysis. (5thEdition), New Jersey-U.S.A: Prentice Hall.

GSS (2014). Ghana Living Standards Survey round 6 (GLSS6). Poverty profile in Ghana (2005-2013). Ghana Statistical Service.

GSS (2008). Ghana Living Standards Survey: Report on the fifth round (GLSS5) Accra, Ghana, September, Ghana Statistical Service.

Heckman JJ (1976). The common structure of statistical models of truncations, sample selection and limited dependent variables and a simple estimator for such models. Ann. Econ. Soc. Meas. 5:475-92.

Heckman JJ (1979). Sample selection as a specification error. Econometrica 47:153-161.

Hillocks RJ, Bennett C, Mponda OM (2012). Bambara Nut: A review of utilization, market potential and crop improvement. Afr. Crop Sci. J. 20(1):1-16.

Ibekwe UC, Eze CC, Onyemauwa CS, Henri-Ukoha A, Korie OC, Nwaiwu IU (2010). Determinants of farm and off–farm income among farm households In South East Nigeria. Acad. Arena 2(10):56-61.

Lacroix B, Assoumou NY, Sangwan RS (2003). Efficient *in vitro* direct shoot regeneration systems in Bambara groundnut (*Vignasubterranea* L. *Verdc.*). Plant Cell Rep. 21:1153-1158.

Linnemann AR (1990). Cultivation of Bambara groundnut (*Vigna Subterranean* (L) Verdc.) in western province, Zambia. Report of a field study. Trop. Crops Comm. pp. 15-19.

Loftas T, Ross J (1995). Dimensions of need: an atlas of food and agriculture. Food and Agriculture organization of the United Nations.

Maddala GS (1983). Limited-Dependent and Qualitative Variables in Econometrics. New York: Cambridge University Press.

Ojimelukwe PC, Ayernor GS (1992). Oligosaccharide composite and functional properties of flour and starch isolate from four cultivars of Bambara groundnut seeds. J. Food Sci. Technol. 29:319-321.

Pasquet RS (2003). Bambara groundnut and Cowpea Gene-pool Organization and Domestication; in: Proc. Intl. Bambara groundnut Symp. Botswana College of Agriculture, Botswana. pp. 263-272

Padulosi S, Hodgkin T, Williams JT, Haq N (2001). 30 Underutilized Crops: Trends, Challenges and Opportunities in the 21st Century. Manag. Plant Genet. Divers. pp. 323-338.

Padulosi S, Hoseschle-zeledon I (2004). Underutilised plant species: What are they? Leisa Magazine.

PROTA (Plant Resources of Tropical Africa) (2006). In Brink M, Belay G (Eds). Cereals and Pulses, PROTA Foundation, Netherlands, pp. 213-217.

Quaye W (2008). Food security situation in northern Ghana, coping strategies and related constraints.

Redjeki ES, Mayes S, Azam-ali S (2011). Evaluating the stability and adaptability of Bambara groundnut (*Vigna subterranean* (L.) Verd.) landraces in different agro ecologies. 2nd International symposium on underutilized plant species held in Kuala Lumpur, Malaysia.

Schultz TW (1975). The value of the ability to deal with disequilibria. J. Econ. Lit. 13(3):827-46.

Sellschop JPF (1962). Cowpeas (*Vigna unguiculata* (L.) walp. Field Crop Abstracts 15:259-266.

The State of the World (SoW) (2011). African indigenous crops. Innovations that nourish the planet. State of the World, 2011.

Uematsu H, Mishra AK (2010). Net Effect of Education on Technology Adoption by U.S. Farmers. Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Orlando.

Williams JT, Haq N (2002). Global research on underutilized crops. An assessment of current activities and proposal for enhanced cooperation. International Centre for Underutilised Crops, University of Southampton United Kingdom.