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Full Length Research Paper

Fertilizer subsidy policy and smallholder farmers' crop productivity: The case of maize production in North-Eastern Ghana

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Crop yield enhancing technologies such as inorganic fertilizers present opportunities for improving smallholder farmers' crop yields, food security and incomes. This study examines maize productivity response to Ghana's fertilizer subsidy policy focusing on yield differences between participants and non-participants in the Tempene District in Ghana among smallholder farmers. An Endogenous Switching Regression (ESR) model is employed to simultaneously examine the determinants of participation and its impact on maize productivity. The results show that education, nativity and media access are factors influencing the probability of fertilizer subsidy participation. The study reveals that participation in subsidized fertilizer policy is positively and significantly associated with maize productivity. Other factors such as fertilizer use rate, improved seeds and age enhance maize yield whilst non-farm work engagement negatively influences maize yield. These findings suggest that the impact of subsidized fertilizer on maize productivity can be enhanced with proper targeting and farmer education through field demonstrations.

Key words: Subsidized fertilizer, maize yield, endogenous switching regression, Northern Ghana.

INTRODUCTION

Agriculture is the main source of livelihood for the majority of people in developing countries where crop production methods are dominated by traditional practices. Farmers in Sub-Saharan countries have traditionally cleared virgin lands, grown crops for a few seasons and then moved on to clear more land. This practice left the abandoned land to fallow, allowing it to regain its fertility over time. However, constant population

growth has compelled farmers to continually plant crops on the same land giving no time for the soils to replenish the lost nutrients (Mokwunye and Bationo, 2011). The resulting effect has been soil nutrient depletion which has led to declining per capita food production (Mwangi, 1996), increased food insecurity and high poverty rates, especially in African countries. For smallholder farmers to feed themselves and to increase their incomes, then the

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use of modern methods of production that improve and restore soil fertility is paramount.

The use of inorganic fertilizers to restore and maintain soil fertility for increased crop productivity has been generally acclaimed as very necessary among researchers and policy makers (Chapoto and Ragasa, 2013; Duflo et al., 2011; Mokwunye and Bationo, 2011). However, farmers in Africa may not be in the position to optimize fertilizer use because either they cannot afford or that fertilizer may not be readily available. As indicated by Druilhe and Barreiro-Hurlé (2012), while Sub-Saharan African farms are highly deficient in nutrients, fertilizer use is very low, with only 7 kg/ha application rate compared to more than 150 kg/ha in Asia (Fearon et al., 2015). The low rates of use of fertilizers are largely the result of limited smallholder farmers' access, high cost and limited availability of fertilizers in the local community. These circumstances therefore make subsidy programmes economically justified to address the market failures and the poor incentives faced by farmers.

Subsidy programmes were suspended as part of the Structural Adjustment Programme (SAP) and market liberalization policies adopted by African governments in the 1980s and 1990s (Chibwana et al., 2010; Minot and Benson, 2009). The combined effect of production stagnation, declining soil fertility and rising food insecurity however, led to fresh interest in promoting input subsidies as a tool for addressing food insecurity. The Abuja declaration on fertilizer for a "Green Revolution" which has the objective of increasing fertilizer use to 50 kg/ha by 2015 (AU, 2006) was adopted at the 2006 Africa Fertilizer Summit held in Abuja to address agricultural productivity challenges.

In 2008, Ghana re-introduced the fertilizer subsidy programme with the core objective of raising productivity/production in line with government's commitment to ensure food security and to improve the living standards of Ghanaians. The new programme, per the recommendations of the Abuja Summit, was expected to help increase fertilizer usage to at least 50 kg/ha by 2015. A proper implementation of such a subsidy programme could trigger both short term and long term development, not only in the agricultural sector but in other sectors of the economy. For example, effective subsidies can raise both land and labour productivities, as well as drive down staple food prices, which have the multiplier effect of raising real incomes, enhancing local labour demand and wages and improving the people's nutrition (Kassie et al., 2011). The reintroduction of the fertilizer subsidy programme was, therefore, to address the challenges confronting the development of the agricultural sector generally and specifically to increase crop production and productivity for sustainable food security, with particular attention to smallholder farmers (Benin et al., 2013) cultivating maize, rice, sorghum and millet (Fearon et al., 2015). Between 2008 and 2012, Ghana's annual spending on subsidized

fertilizers grew by over 4 folds, amounting to GH¢20.6 million in 2008 and GH¢117.4 million in 2012 (Fearon et al., 2015).

Maize, being the largest and most important staple crop in Ghana, accounts for over 50% of cultivated land in the country with its production being dominated by smallholder farmers who usually rely heavily on rain fed conditions with limited use of fertilizers and other inputs due to high cost of such inputs (MoFA, 2011, 2013). The on-going fertilizer subsidy falls in line with government's commitment to boost the production of staple food crops including maize to cope with the ever growing demand for maize and poverty associated with smallholder farmers (MoFA, 2017). Increasing maize crop productivity can simultaneously release resources for the production of non-staple foods and non-farm goods and services.

While a lot of studies on fertilizer subsidy abound in Ghana and elsewhere (Azumah and Zakaria, 2019; Benin et al., 2013; Chapoto and Ragasa, 2013; Chibwana et al., 2010; Duflo et al., 2011; Imoru and Ayamga, 2015; Mather and Jayne, 2018; Yawson et al., 2010), not much of it has focused on how specifically fertilizer subsidy policy has affected maize production especially in the north-eastern corner of Ghana where possible smuggling activities could render the programme ineffective. Even after some reforms were made to the distribution format for subsidized fertilizers recently, smuggling of subsidized fertilizers from Ghana to neighbouring countries persisted (Benin et al., 2013; Resnick and Mather, 2016). For some reasons including alleged smuggling of subsidized fertilizers, in July 2019 retail distribution of fertilizer was banned in nine districts located in the north-eastern corridors of the country and these included the Tempene District. The study by Azumah and Zakaria (2019) examined the effects of subsidized fertilizers on rice productivity, whilst those of Yawson et al. (2010) and Imoru and Ayamga (2015) centred on subsidized fertilizer use and use intensity. In their study, Azumah and Zakaria (2019) found that the adoption of subsidized fertilizer had a negative and significant impact on rice yield. Some studies on subsidized fertilizer and maize production include Chapoto and Ragasa (2013) for Ghana and Chibwana et al. (2010) for Malawi using different approaches. Previous studies on the effect of fertilizer subsidy on maize yield (Chapoto and Ragasa, 2013) employed Ordinary Least Squares (OLS), a model that fails to account for selection bias. The use of OLS to assess the effect of a possible endogenous variable, such as farmers' decision to adopt or not to adopt subsidized fertilizer, on maize productivity could be flawed due to endogeneity problems and selectivity bias. This study therefore examines productivity differences between fertilizer subsidy beneficiaries and non-beneficiaries in the Tempene District, located at the north-eastern corner of Ghana and part of the Upper East Region, among smallholder farmers engaged in maize production.

In assessing the impact of a given policy such as fertilizer subsidy like in the present study requires the use of an appropriate method that is capable of establishing a suitable counterfactual against which the impact can be measured (Asfaw et al., 2012; Kassie et al., 2011; Nonvide, 2018). This study therefore uses an Endogenous Switching Regression (ESR) approach which can help estimate counterfactual outcomes and account for possible endogeneity due to selectivity bias that may be associated with farmers' decision to use subsidized fertilizer and maize productivity.

MATERIALS AND METHODS

Theoretical framework and econometric model

In this study, farmers' decision to adopt/use subsidized fertilizers is modeled based on the expected utility maximization theory. The farmer adopts subsidized fertilizer only if the expected utility derived from adoption exceeds that from not adopting. In this case, the farmer's direct expectation in adopting subsidized fertilizer is better or higher crop (maize) yield. This implies that, adoption of subsidized fertilizer becomes the selection criterion indicating the scenario faced by farmers and following earlier studies on impact analysis (Donkoh et al., 2016; Issahaku and Abdulai, 2019; Mwangi and Crewett, 2019; Nonvide, 2018; Simtowe et al., 2009), subsidized fertilizer adoption function can be represented by:

$$S_i^* = \delta D_i + V_i \quad (1)$$

where S_i^* is a latent variable indicating a farmer's subsidized fertilizer adoption status; D_i is a vector of household and farm characteristics, assumed to affect farmer's decision with respect to subsidized fertilizer adoption; δ is a vector of parameters to be estimated and V_i is a random error term. It follows from Equation 1 that a farmer is a beneficiary of subsidized fertilizer given that $S_i^* > 0$. Farmers are categorized as beneficiaries if they have benefitted from the fertilizer subsidy programme for at least, in the immediate past two years conservatively and non-beneficiaries if they have not used subsidized fertilizers as described. The observable dichotomous variable S_i indicating whether or not a farmer is a beneficiary of subsidized fertilizer can then be defined as follows:

$$S_i = \begin{cases} 1 & \text{iff } \delta D_i + V_i > 0 \\ 0 & \text{iff } \delta D_i + V_i \leq 0 \end{cases} \quad (2)$$

where $S_i = 1$ indicates that the farmer has benefitted from fertilizer subsidy and $S_i = 0$ indicates otherwise.

Defining farmers' maize productivity to be a linear function of adoption of subsidized fertilizers along with other observed variables, the linear regression equation can be specified as

$$Y_i = \beta X_i + \delta S_i + U_i \quad (3)$$

Where Y_i is maize productivity, X_i is a vector of farmer, household and farm characteristics, β is a vector of parameters to be estimated, U_i is a random error term with S_i , δ and V_i as defined earlier.

Applying OLS techniques to estimate the impact of fertilizer subsidy adoption on maize productivity using Equation 3 may

produce biased and inconsistent estimates. This might be so because, farmers' decision to use subsidized fertilizer is assumed exogenous by Equation 1, but this could be potentially endogenous (Heckman, 1979) since farmers' decision to adopt or not to adopt subsidized fertilizer may be voluntary and could be based on individual self-selection. Under such cases, the impact of subsidized fertilizer adoption needs be isolated from the observed and unobserved socioeconomic and farm variables that determine maize productivity and subsidized fertilizer adoption status of farmers. For example, unobserved factors influencing the adoption decision which may include farmers' personal traits (ability and skills) (V_i) may correlate with unobserved factors that influence the outcome variable (U_i), maize productivity, resulting in biased and inconsistent coefficient estimates. On the account of the two sub-groups of maize farmers, two outcome scenarios emerge and can be stated as follows:

Scenario 1: $Y_{i1} = \beta X_{i1} + U_{i1}$ for subsidized fertilizer beneficiaries

Scenario 2: $Y_{i0} = \beta X_{i0} + U_{i0}$ for non-subsidized fertilizer beneficiaries (4b)

where Y_{i1} and Y_{i0} are respectively, maize productivities of beneficiaries and non-beneficiaries of subsidized fertilizer; X_i , β and U_i are as defined earlier.

Due to the likelihood that some unobserved factors affecting farmers' adoption of subsidized fertilizer decisions could also affect some unobservable factors affecting maize yield (outcome variable), the error term in Equation 1 and the error terms in the outcomes functions (Equations 4a and b) may be correlated as noted earlier. To account for this, a simultaneous equations model of fertilizer subsidy adoption and maize productivity was estimated using an ESR based on a Full Information Maximum Likelihood (FIML) technique following earlier studies (Asfaw et al., 2012; Issahaku and Abdulai, 2019; Nonvide, 2018).

As estimates of expected maize yield of fertilizer subsidy beneficiaries and non-beneficiaries as well as the associated counterfactuals are important for explaining differences in maize yield between the two sub-groups, ESR enables the estimation and comparison of the expected maize yield. In this regard, the expected maize yields of fertilizer subsidy beneficiaries (i) to that of non-beneficiaries (ii). It is also possible to estimate the expected maize yield in the counterfactual cases; (iii) that beneficiaries did not benefit from the subsidy programme and (iv) that non-beneficiaries did benefit from the programme. Reported in Table 1 are the conditional expectations of maize yield in cases (i) through (iv) with cases (i) and (ii) indicating actual maize yield expectations, while the counterfactual expected outcomes are represented by cases (iii) and (iv).

In Table 1, TT is the estimate of the effect of the treatment on the treated, calculated as $TT = E(Y_{i1}|S_i = 1) - E(Y_{i1}|S_i = 0)$. TT therefore measures the effect of fertilizer subsidy adoption which is the difference between cases (i) and (iii). The effect of the treatment on the untreated is defined as TU, calculated as $TU = E(Y_{i0}|S_i = 1) - E(Y_{i0}|S_i = 0)$ and this is the difference between cases (iv) and (ii), reflecting a scenario where non-subsidy beneficiaries did adopt and where they (non-beneficiaries) did not adopt. To segregate the treatments effects from heterogeneity effects arising from the possibility that beneficiaries may have more or less yield than non-beneficiaries, regardless of the fact that they benefitted from subsidized fertilizer, BH_1 is calculated as the base heterogeneity effect using the formula $E(Y_{i1}|S_i = 1) - E(Y_{i0}|S_i = 1)$. Such difference could rather be due to unobservable factors that affect maize productivity. It is the difference between cases (i) and (iv). In contrast, BH_0 is the base heterogeneity effect for farmers that did not benefit and measured as $E(Y_{i1}|S_i = 0) - E(Y_{i0}|S_i = 0)$ which is the difference between cases (iii) and (ii). Finally, to determine

Table 1. Maize yield expectations, treatment effects and heterogeneity effects.

Sub-sample	Decision stage		Treatment effects
	Benefit	Do not benefit	
Beneficiaries	(i) $[Y_{i1} S_i = 1]$	(iii) $[Y_{i1} S_i = 0]$	TT
Non-beneficiaries	(iv) $[Y_{i0} S_i = 1]$	(ii) $[Y_{i0} S_i = 0]$	TU
Heterogeneity effect	BH ₁	BH ₀	TH

Source: Di Falco et al. (2011); Asfaw et al. (2012).

whether or not the effect of fertilizer subsidy on maize yield is greater or less for beneficiary or for non-beneficiary farmers if they did benefit, a transitional heterogeneity effect (TH) was calculated by taking the difference between TT and TU (TH = TT – TU).

Study area, sampling and data

The study was conducted in the Tempene District which is located in the north-eastern part of the Upper East Region and lies between latitude 10° 10'N and Longitude 00° 10'W. It is bordered to the east by the Republic of Togo, to the north by Burkina Faso, to the west by the Bawku Municipality and to the south by the East Mamprusi District. The district has an area of 1,230 km² and a population density of 99 persons per square kilometer. The climate is characterized by a unimodal rainy season which occurs between May/June to September/October with an average amount of rainfall of 800-860 mm per annum. The vegetation is mainly Sahel savannah, consisting of scattered drought resistant trees and grasses. The district is predominantly rural with the main occupation being farming and an estimated total farmer population of 80-90% (GSS, 2012). Farmers in the district engage in the cultivation of cereals, legumes vegetables as well as tree crops.

Sample selection for the study followed a multi-stage procedure. The Tempene District was purposely selected because of its location as the north-eastern most district bounded by two neighboring countries (Togo and Burkina Faso) in the first stage. The second stage involved a random selection of five communities including Nintanbugasuk, Sunugu, Tempene, Gagberi and Busum. In the third stage, a stratified sampling technique was employed to group farmers as beneficiaries of subsidized fertilizers and non-beneficiaries of subsidized fertilizer. In the fourth and final stage, a simple random sampling method was used to select 15 respondents from each stratum in each community, giving two sub-samples of 75 subsidized fertilizer beneficiaries and 75 non-beneficiaries of subsidized fertilizer. A total of 150 respondents therefore consisted the sample for the study. A semi-structured questionnaire was used in collecting the relevant data for the study. Data were collected on the socioeconomic characteristics of farmers at both the household and individual levels as well as farm characteristics between November and December 2018.

Descriptive results

Summary statistics of respondents in the study indicate no statistical differences between beneficiary and non-beneficiary farmers of subsidized fertilizer (Table 2) with respect to a number of factors. In particular, beneficiary farmers were not different from non-beneficiary farmers in terms of marital status, level of formal education, access to credit, engagement in non-farm activities, access to extension services, mean distance to the nearest market and non-nativity status of farmers. Significant differences between beneficiaries and non-beneficiaries were however found to include

maize yield per unit of land area, farmers' age and gender, household size, farm size, fertilizer use rate, the use of improved maize seeds, community influence and access to media (Table 2).

Overall, the mean yield of maize for all farmers was 10.63 maxi bags per hectare which is approximately 1,063 kg/ha according to the conversion rate used by MoFA¹. Beneficiaries of fertilizer subsidy had about 1,143 kg/ha compared to their non-beneficiary counterparts who had less (979 kg/ha) than the global mean yield. Beneficiaries were much older than non-beneficiaries indicating that older farmers had better access to subsidized fertilizer in the Tempene District.

Generally, households consist of larger membership (10) compared to national average (4) (GSS, 2014a) and beneficiaries had more household members (13) than non-beneficiary households (7). The small size of farm lands signals a serious challenge of access to land for farming purposes in the Tempene District as on the average, a typical farmer has less than 1.5 ha (1.47 ha). This is far below the Ghana Statistical Service estimate of 2 ha of land size cultivated by smallholder farmers in Ghana (GSS, 2014b). The results however reveal a higher average farm size among fertilizer subsidy beneficiaries (1.67 ha) relative to an average farm size of 1.25 ha among non-beneficiary farmers. The study reveals a generally low fertilizer application rate (6.2 kg/ha) among farmers compared to estimates by earlier studies such as Benin et al. (2013). There were however significant differences between subsidized fertilizer beneficiaries (6.67 kg/ha) and non-beneficiaries (5.58 kg/ha). The use of improved maize seeds for planting appears very scanty as less than 10% of farmers reported using improved seeds during the 2018/2019 farming season. However, there were more beneficiary farmers (14.4%) than non-beneficiaries (4.1%) who used improved seeds. While a little over 10% (11.7%) of beneficiary farmers had influence at the community level, only 4.1% of non-beneficiaries had such influence. There was also significant difference between beneficiary and non-beneficiary farmers with respect to access to media which could make beneficiaries more exposed and well informed of development interventions compared to their non-beneficiary counterparts.

RESULTS AND DISCUSSION

Determinants of subsidized fertilizer participation and maize yield in the Tempene District

Results of the estimates of the ESR (Table 3) show a significant Wald test of independent equations at 1% level, confirming the sample separation and that the model has a good fit with its explanatory variables. The

¹ A maxi bag of maize gains is approximately 100kg according to the Ministry of Food and Agriculture (MoFA).

Table 2. Variables and summary statistics of respondents.

Variable	Total (150)	Beneficiaries (75)	Non-beneficiaries (75)	Mean difference	t-test/ χ^2
Maize productivity (kg/ha)	1.063	1.143	979	163	3.42***
Married farmer	0.933	0.935	0.931	0.004	0.087
Age	42.2	47.1	37.1	10	5.83***
Male farmer	0.733	0.792	0.671	0.121	1.68**
Education level	7.64	6.1	9.3	-3.16	-5.35
Household size	10	13	7	6	5.71***
Farm size	1.47	1.67	1.25	0.42	4.8***
Fertilizer application/ha	6.2	6.78	5.58	1.2	3.81***
Improved seeds	0.0933	0.143	0.041	0.102	2.16**
Credit	0.093	0.117	0.068	0.048	1.025
Non-farm activity	0.113	0.078	0.151	-0.073	-1.405
Extension services	0.033	0.026	0.041	-0.0151	-0.513
Farm-Market distance	3.38	3.35	3.41	-0.06	-0.308
Non-Native	0.353	0.377	0.329	0.048	0.609
Community influence	0.08	0.117	0.041	0.076	1.715*
Media	0.307	0.506	0.096	0.411	6.046***

Source: Field Survey November/December 2018. ***, ** and * indicates statistical significance levels of 1, 5 and 10% respectively.

coefficient of correlations of the error terms between the selection equation and each of the two outcome equations, Rho_1 and Rho_0 , are both significant at the 1% level. The positive coefficient of Rho_1 signals a negative selection bias, which implies that farmers with maize yields lower than average without the fertilizer subsidy policy actually participated in the fertilizer subsidy programme. The negative and significant coefficient of Rho_0 shows a positive selection bias, meaning that farmers with maize yields more than average without the policy, did not actually adopt subsidized fertilizer (Abdulai and Huffman, 2014; Lokshin and Sajaia, 2004). These results suggest that in the Tempene District, maize farmers who perceive themselves as less productive are more likely to participate in the subsidized fertilizer programme whilst those who consider themselves more productive were more likely not to participate in the programme and this has an implication for programme targeting which is very important for effective input subsidy policy roll outs (Mather and Jayne, 2018).

The drivers of subsidized fertilizer adoption in the Tempene District are reported in the last column of Table 3. Significant factors informing farmers' decisions regarding the use of subsidized fertilizers are education, nativity and access to the media. Whilst education and being a non-native negatively influence farmers' fertilizer subsidy decisions, having access to the media has a positive impact on farmers' decision to use subsidized fertilizers. The inverse relationship between subsidized fertilizer adoption and farmers' education attainment may

be as a result of the fact that educated farmers are more endowed and hence can purchase fertilizer at the market price compared to non-educated farmers. It could also be attributed to the fact that educated people might not be doing farming as their main economic activity and hence, their investment on farm operations is less in terms of fertilizer application. The finding on farmers' education finds support in a recent study, Azumah and Zakaria (2019), which analyzed fertilizer subsidy programme participation and rice productivity in northern Ghana.

The results also revealed an inverse relationship between the non-native status of farmers and subsidized fertilizer programme participation. This suggests that farmers who are natives tend to have access to subsidized fertilizers and therefore are more likely than non-natives to adopt the product. This makes intuitive sense as non-native farmers could just be settlers who may face challenges in doing so because they may be treated as outsiders. Similar finding on nativity was reported in Martey et al. (2014). Media access is also an important determinant of subsidized fertilizer programme participation as the coefficient of media is significant and positive at the 1% level. As found in earlier studies, farmers who own communication facilitating equipment such as radio and television are more likely to have information on policy interventions that target farmers and their operations (Azumah and Zakaria, 2019).

The significant determinants of the maize yield among subsidized fertilizer beneficiaries and non-beneficiaries as reported in the second and third columns of Table 3

Table 3. Estimates of the impact of fertilizer subsidy participation on maize yield.

Variable	Maize yield model		Fertilizer subsidy participation model
	Beneficiaries	Non-beneficiaries	
Married farmer	1.074 (0.999)	-0.240 (1.168)	-0.175 (0.439)
Age of farmer in years	0.0705 (0.0409)*	-0.0148 (0.0602)	0.00638 (0.0222)
Male farmer	-0.0392 (0.594)	-0.216 (0.716)	0.350 (0.281)
Household size	-0.0782 (0.0659)	-0.0840 (0.106)	0.0245 (0.0399)
Farm size in hectares	0.278 (0.623)	0.300 (1.153)	-0.232 (0.411)
Fertilizer rate (hectare)	1.078 (0.159)***	0.745 (0.212)***	0.126 (0.0791)
Used improved seeds	3.197 (0.843)***	3.865 (1.532)**	0.137 (0.834)
Access to credit	-1.234 (0.813)	-1.895 (1.474)	0.664 (0.408)
Non-farm work	-2.156 (0.869)**	0.343 (0.918)	0.201 (0.372)
Extension advice	1.236 (1.369)	-0.702 (1.418)	0.234 (0.591)
Years of education	0.0674 (0.0852)	0.133 (0.182)	-0.109 (0.0542)**
Market distance (km)			-0.0761 (0.0926)
Non-native farmer			-0.476 (0.222)**
Community leadership			-0.259 (0.791)
Access to media			0.784 (0.257)***
Constant	-1.436 (1.976)	4.077 (2.991)	0.0234 (1.073)
Observations	75	75	150
rho_1	0.967 (0.051)***		
rho_2	-0.899 (0.1029)***		
Log likelihood	-373.4605		
Wald Chi² (11)	162.91		
Prob>Chi²	0.0000		
Likelihood test of independent equations			
Chi²(1)	22.18		
Prob>Chi	20.0000		

Source: Field Survey Data, November/December 2018. ***, ** and * indicates statistical significance levels at 1, 5 and 10% respectively. Standard errors are in parentheses.

are fertilizer application rate and the use of improved maize seeds. For the two regimes of subsidized fertilizer beneficiaries and non-beneficiaries, fertilizer application rate and the use of improved maize seeds contribute significantly to higher output of maize. The results collaborate empirical findings of technological input adoption and crop yield (Chapoto and Ragasa, 2013; Denning et al., 2009; Mwangi, 1996; Scheiterle et al., 2018; Theriault et al., 2018; Yawson et al., 2010). Additional factors that determined maize yield among beneficiary farmers were farmers' age and non-farm work. While age had a positive effect on maize yield, participation in non-farm work tends to reduce yield. The finding on age of the farmer implies experience of the farmer is important for increasing maize productivity as older farmers are assumed to have long periods of farming compared to younger farmers (Imoru and Ayamga, 2015) but this is contrary to the findings of

Chibwana et al. (2010) that the age of the farmer reduces maize yield in Malawi.

The study, in examining the impact of subsidized fertilizer on farmers' maize productivity estimated expected maize yield under the counterfactual scenarios of fertilizer subsidy beneficiaries and non-beneficiaries (Table 4). The observed maize productivities for beneficiaries (11.47 maxi bags/ha or 1,147 kg/ha) and non-beneficiaries (9.81 maxi bags/ha or 981 kg/ha) are indicated in cases (i) and (ii) respectively which were found to be significantly different at the 1% level based on a test of difference of means (t-test). In the counterfactual case (iii), the mean maize yield of beneficiary farmers would have been 6.99 maxi bags/ha or 699 kg/ha of maize, had they not benefited. The results suggest that farmers who benefitted from the subsidy programme are better off as their observed productivity (1,147 kg/ha) is much higher than their

Table 4. Mean expected maize yield per hectare for subsidy beneficiaries and non-beneficiaries.

Sub-sample	Decision stage		Treatment effects
	Benefited	Did not benefit	
Beneficiaries	(i) 11.47 (0.329)	(iii) 6.99 (0.243)	TT=4.48 (0.413)***
Non-Beneficiaries	(iv) 7.15 (0.309)	(ii) 9.81 (0.197)	TU=-2.66 (0.371)***
Heterogeneity effects	BH1=4.32 (0.452)***	BH2=-2.82 (0.313)***	TH=7.14 (0.235)***

Source: Field Survey November/December 2018. ***indicates statistical significance level at 1%.

counterfactual productivity of 699 kg/ha. This is demonstrated by the positive significant difference of the Treatment on the Treated (TT) at the 1% level [4.48 (0.413)].

For non-beneficiaries, the average maize productivity would have been 7.15 maxi bags or 715 kg/ha had they decided to use subsidized fertilizer. When compared with their observed productivity, non-beneficiaries of fertilizer subsidy in this study are better off with their decision not to be part of the programme since their observed maize yield (981 kg/ha) is much higher than their counterfactual mean productivity (715 kg/ha). This result is confirmed by the negative significant difference of -2.66 (0.371) which is an estimate of the effect of the Treatment on the Untreated (TU). This finding suggests that non-beneficiaries of subsidized fertilizer in the Tempene District are rational as they tend to make decisions that help in optimizing returns to their maize production goals. Overall, these findings imply that while fertilizer subsidy policy increased maize productivity among programme beneficiaries, non-beneficiaries are not also worse off for their decision not to join the programme. Furthermore, from the estimated Transitional Heterogeneity (TH) effect, the results show a positive and significant TH (7.14 (0.235) implying that the effect of subsidized fertilizer was greater among beneficiary farmers than their non-beneficiary counterparts. Beneficiary farmers produced 714 kg/ha more than non-beneficiaries, if they (non-beneficiaries) actually benefitted from the policy. While the findings of this study are in line partly with the policy objectives underlying Ghana's fertilizer subsidy programme of raising crop productivity among smallholder farmers (MoFA, 2017) and confirms some previous empirical studies (Chibwana et al., 2010), the findings nonetheless, contradict some earlier studies that produced decreasing effect of subsidized fertilizer use on crop yield (Azumah and Zakaria, 2019) and yet others found that the programme was largely ineffective (Fearon et al., 2015; Imoru and Ayamga, 2015).

CONCLUSION AND RECOMMENDATIONS

The paper analyzed the impact of Ghana's fertilizer subsidy programme on maize productivity in the north-eastern corner of the country. The major determinants of

programme participation are education, media access and nativity status of farmers. The study found fertilizer application rate and the use of improved seeds as factors contributing to increased maize yield for both programme beneficiaries and non-beneficiaries. Age and non-farm work participation are additional factors that influence maize yield for programme participants with age affecting maize yield positively and non-farm work having a decreasing effect on maize yields, a finding that suggests a labor loss effect of non-farm work engagement. It is therefore recommended that the goal of the policy on subsidized fertilizer that targets smallholder farmers could be realized if education campaign on the importance of using the right quantity of fertilizer per land area is carried out and as well as making improved crop seed varieties accessible to farmers. The findings on age and non-farm work provide a guide for programme targeting if the objectives of the fertilizer subsidy policy are to be achieved.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Analysis of the profitability and marketing distribution channels of sweet potato business in Sierra Leone

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The objective of this study is to examine the profitability and channels of distribution of sweet potato in Sierra Leone. Multistage sampling was used to select 150 sweet potato marketers from five major districts. Data was collected on socio-economics characteristics, distribution channels, market margins and net income, drivers and barriers of sweet potato marketers with aid of android devices programme with the Census and Survey Processing System (CSPro. 6.3) software package. The data was analysed using descriptive statistics. Sweet potato trading investment has a net positive return. After calculating the benefit-cost ratio (BCR), the BCR of sweet potato root trading in each of the districts was greater than one (BCR>1), which indicates that, sweet potato roots trading business is profitable. The revenue generated in the sale of one (1) bag of sweet potato is high. That is, an average of 20% profit is realised from the 1 bag (50 kg) that is bought and sold and the highest profit was realised in Bombali district. Therefore, sweet potato trading is a profitable and a lucrative business venture in Sierra Leone that is worth investing. Lack of credit facilities, inadequate initial capital and high transportation costs were identified as the major factors militating against sweet potato marketing in the study area. The study therefore recommended, the government as well as non-governmental agencies should organise the marketers into groups and empower the marketers through the provision of micro credit facilities to increase the initial capital and hence expand in trading of sweet potato roots.

Key words: Distribution channels, drivers and barriers, marketing margin and net profit, sweet potato.

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is a major Root and tuber crops for direct human consumption in the world especially Africa, yet it is one of the least marketed. It is among the world's most important, versatile, and under exploited food crops, with more than 133 million tonnes (FAOSTAT, 1997/1998; FAOSTAT, 2015) in annual production. Presently within the global market trend, sweet potato is ranked 27th, 0.3% shares of world imports and also ranked 117th, 0.0% shares in global

exports market. China (67.1%) is the current leading producers of sweet potato followed by Nigeria (3.7%); but United States (1.4%) which is the 9th producing countries controls the largest share in export (38.9%) market of sweet potato than China (6.5%) and Nigeria (0.0%) and United Kingdom as the top importers in the world (statistics of HS code 071420, 2016). Among the root and tuber crops, it is the only crop that has a positive per capita annual rate of increase in production in sub-

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Saharan Africa (Bashaasha and Mwanga, 1992).

Sweet potato is cultivated in all the 14 districts in Sierra Leone and the north is recorded as the highest producing region. Its contributes 2.9% towards the total national food production which indicates that, the number of households producing sweet potatoes is relatively lower than those producing cassava and rice in Sierra Leone. The sweet potato crop is used for both subsistence and commercialization purposes and hence 11% of agricultural household's countrywide sold all their sweet potato crop, 62.8% sold part of their crop and 26.2% sold none at all locally (SSL, 2004). Marketing opportunities for sweet potato abound; demand for sweet potato roots and leaves, especially in the urban areas is large but the market is not adequately organized. The potential for the industrial use of sweet potatoes (especially high yielding improved varieties) exists but is currently not being exploited. Value-added activities are limited to preparing into other food forms. Preserving the fresh produce shelf-life remains a major challenge to farmers, traders and consumers across Sub-Sahara Africa. Traders often attempt to sell-off their sweet potato produce within 3-4 days upon arrival to avoid decay losses. The practice of disposing off the harvested produce results in seasonal glut; this leads to low prices which affect the economic returns to sweet potato value chain actors. Its bulkiness and perishability with a low shelf life after harvesting limit its economic viability. About 22% of agricultural households produce sweet potato (USAID-BEST 2009). Similar to the case of cassava, post-harvest losses are high. Nonetheless, national production is considered to exceed the national requirement (WFP, 2013). Local traditional sweet potato varieties are grown in Sierra Leone, but vitamin-fortified varieties are not present

Notwithstanding the potential of sweet potato in helping to meet Sierra Leoneans food needs and reduce poverty levels through income generation, detailed information on the sweet potato demand relations is not available to enable the farmers, wholesalers and retailers plan their sweet potato production and marketing activities. The lack of proper planning as a result of insufficient market information is partly evidenced by the high poverty levels in the major sweet potato growing regions. According to Arene (1999), efficiency is used to evaluate marketing performance. Performance can be achieved using the following approaches-marketing margin, net-returns and marketing efficiency ratios. Therefore, there is the need to assess the performance of the market to determine the efficiency of the sweet potato marketing system in Sierra Leone. Hence, the study aims at identifying the socio-economic characteristics of sweet potato traders, assessing the general sweet potato trading activities, identifying the various sweet potato roots distributional channels, determining the marketing margins and net profits and identifying the drivers and barriers of sweet potato trading in Sierra Leone.

Sweet potato production has been found to be

profitable (Ogbonna et al., 2007). Considering its profitability and the increases in sweet potato production after the war and the dreadful Ebola virus and the inability of the increases to be reflected in the marketing system as stated by Low et al. (2009), the attributes towards the inefficiencies in the marketing system of sweet potatoes are inadequacies of storage, processing, transportation and perishability. This is because, the production data of sweet potato from 2000 to 2016 show that, the sweet potato production level has been increasing in Sierra Leone but the increase has not been able to trigger the export of any of its sweet potato products in the international market and therefore ranked 1577th, 0.0% shares of Sierra Leone's exports. The question to be addressed is how efficient is the sweet potato marketing system? Or how well is the sweet potato marketing system performing? Sweet potatoes - yield of Sierra Leone increased from 30,769 hg/ha in 1969 to 74,149 hg/ha in 2018 growing at an average annual rate of 3.10%. This study reports the findings of the profitability and channels of distribution of sweet potato production in the study area. The specific objectives of this study are to:

- (i) Determine the socio-economic characteristics of the sweet potato growers in Sierra Leone
- (ii) Identify the channels of distribution of sweet potato in Sierra Leone
- (iii) Analyse the profitability of sweet potato and
- (iv) Identify the drivers and barriers faced by sweet potato growers in Sierra Leone.

METHODOLOGY

Study locations

The market study was conducted within the five major districts in Sierra Leone which is a Representative of all the regions such as Western (Western Area), North (Bombali), South (Moyamba and Bo) and East (Kenema). The criterion for selecting those districts was based on Njala Agricultural Research Centre (NARC) Research operational zones especially on the Orange Flesh Sweet Potato (OFSP). Due consideration was also given to the production and marketing level of sweet potato tubers within each region. From Figure 1, the red dots within each district indicate the locations where the market data were collected in Sierra Leone.

Sampling frame, selection procedure and size

The sampling frame consists of sweet potato marketers. The frame comprises key marketers within the sweet potato marketing systems in Sierra Leone. Those traders were selected using a multi-stage sampling procedure. The first stage involved the selection of districts using purposive sampling technique which is supported by Kothari (2004). The second stage involved the selection of markets within each district through simple random sampling and the final selection stage (respondent's selection) was through snowballing sampling technique. Traders were selected by scientists with collaboration with heads of markets (Chairperson) who had ideas of traders of sweet potatoes and their locations. This

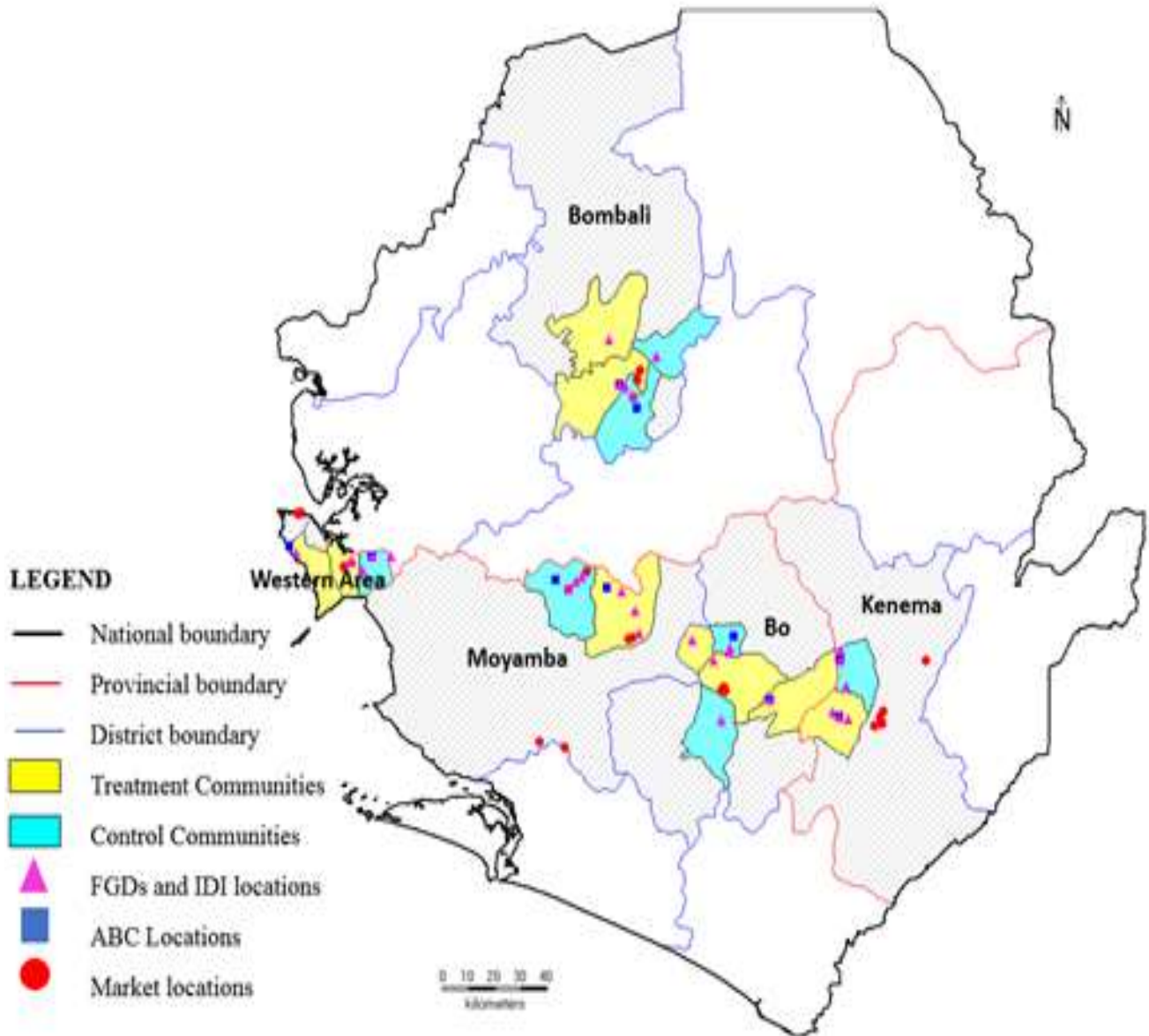


Figure 1. Map of Sierra Leone showing study locations.

Table 1. Sample size of the study.

Data collection method	Sweet potato actor	District					Total
		Moyamba	Bo	Kenema	Bombali	Western area	
Individual interviews	Traders	30	30	30	30	30	150

Source: Survey data (2018).

snowballing sampling technique is often used in hidden populations which are difficult for scientist to access. Sweet potato traders in Sierra Leone were scarce and scattered within the various markets hence majority of those traders who were operating during the data collection timeframe were included in the study. A total of 150 sweet potato traders (30 respondents per district) were selected for

the interview (Table 1).

Data collection

Both primary and secondary data were collected for this study to

Table 2. Socio-economic characteristics of sweet potato traders.

Variable	Category	Moyamba	Bo	Bombali	Western rural	Kenema	Study area
		N=30	N=30	N=30	N=30	N=30	N=150
		%	%	%	%	%	%
Gender	Female	86.7	96.7	100	93.3	96.7	94.7
	Male	13.3	3.3	0.0	6.7	3.3	5.3
Marital Status	Married	80.0	53.3	73.3	73.3	70	70.0
	Single	6.7	46.7	13.3	23.3	3.3	18.7
	Widow / widower	13.3	0.0	10.0	3.3	20.0	9.3
	Divorced / separated	0.0	0.0	3.3	0.0	6.7	2.0

Source: Survey data (2018).

obtain sufficient and realistic information from traders. Primary data involve both qualitative and quantitative collected through individual interviews and personal observation, while secondary data were collected from scientific reports and statistical abstracts used as additional sources of data. The individual interviews were conducted with android devices programme with the Census and Survey Processing System (CSPPro 6.3) software package. The process is called electronic data capture. The types of data collected include socio-economic characteristics of traders, general trading activities, market distributional channels, profitability coefficients and drivers and barriers of sweet potato trading.

Data analysis and presentation

Data collected from the individual marketers' interview were uploaded and exported to various statistical packages: Statistical Analysis Systems (SAS 9.3), Microsoft Excel 2010 and Statistical Package for the Social Sciences (IBM SPSS Statistics 21) for analysis using different analytical tools. Descriptive statistics (mean, frequency percentages and diagrams) was used to analyze the profile of sweet potato traders, general trading activities, market distributional channels, drivers and barriers of sweet potato trading in the study locations. The study also used simple budgeting techniques to determine the market margin (s) and the benefit-cost ratio (BCR) for the various districts. The market margin or the farm-to-retail price spread is the difference between the farm value and the retail price. It represents payments for all assembling, processing, transporting, and retailing charges added to farm products. Marketing margin was computed using Mendoza (1995)'s formula and marketing costs/net returns according to Scarborough and Kydd (1992)'s formula.

$$\Pi = TRS - TTC \quad (1)$$

$$GP = TRS - CPP \quad (2)$$

$$GMM = \frac{TRS - CPP}{TRS} \times 100 \quad (3)$$

$$NMM = \frac{TRS - TTC}{TRS} \times 100 \quad (4)$$

$$BCR = \frac{TRS}{TTC} \quad (5)$$

Where:

Π = Net Profit (s), GP = Gross Profit, TRS = Total revenue from sales per bag of sweet potato, TTC = Total transaction costs (includes both the cost of the product and the market transaction cost), CPP = Cost price of the product per bag of sweet potato, GMM = Gross marketing margins per bag of sweet potato, NMM = Net marketing margins per bag of sweet potato, BCR = Benefit-cost ratio per bag of sweet potato.

RESULTS

Socio-economic characteristics of sweet potato traders

Table 2 shows the gender and marital status of sweet potato traders in the study area. The result in the study area shows that, 94.7% of the traders interviewed were females while 5.3% were males. This implies that sweet potato trading is dominated by females because; the dominance cuts across all districts with Bombali having 100% females. The district with more men in sweet potato trading is Moyamba (13.3%) because most producers see the crop as a cash crop and the production level is very high.

Majority of the sweet potato traders in the study area were married (70.0%), followed by single (18.7%), widow (9.3%) and separated (2.0%). This shows that, sweet potato marketing is dominated by married traders and this dominance goes across all districts within the study locations which is a very good indication of sober market. The district with more married couples among the districts is Moyamba (80.0%), with more singles is Bo (46.7%), more widow and divorced traders can be found in Kenema (20.0% and 6.7%) respectively) (Table 2).

Majority of the traders interviewed at least have formal (54.2%) and non-formal (45.8%) education but bulk of them stop at primary level (27.5%) which is still not sufficient to be literate (Figure 2). Majority of traders that did not attend any formal school can be found in Kenema (63.0%), with primary education in Wester Area (43.0%), junior secondary school in Bo, Bombali and Kenema (each 20%) and at least attempt senior secondary school

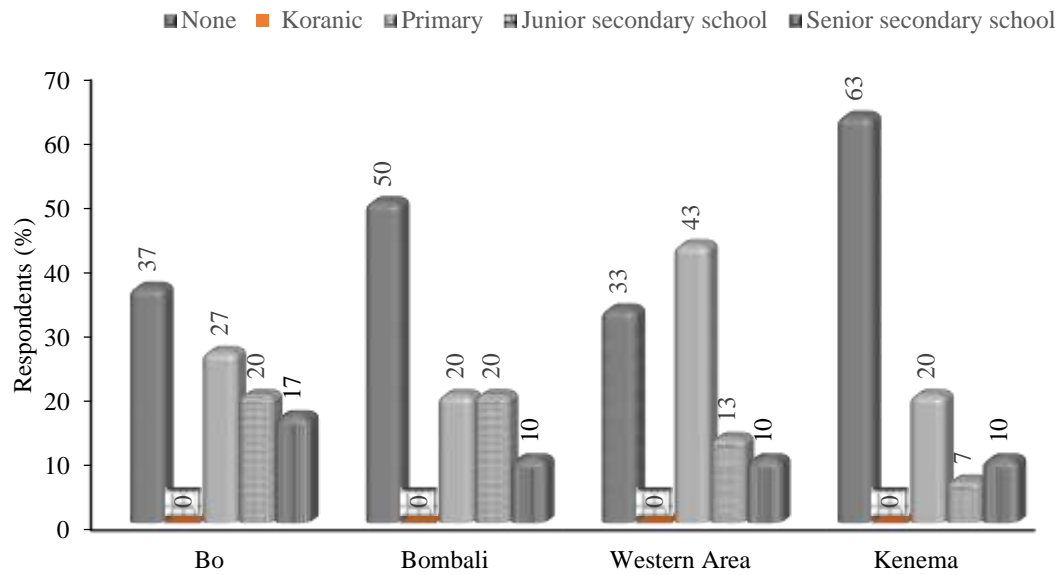


Figure 2. Educational level for sweet potato traders. Source: Survey data (2018).

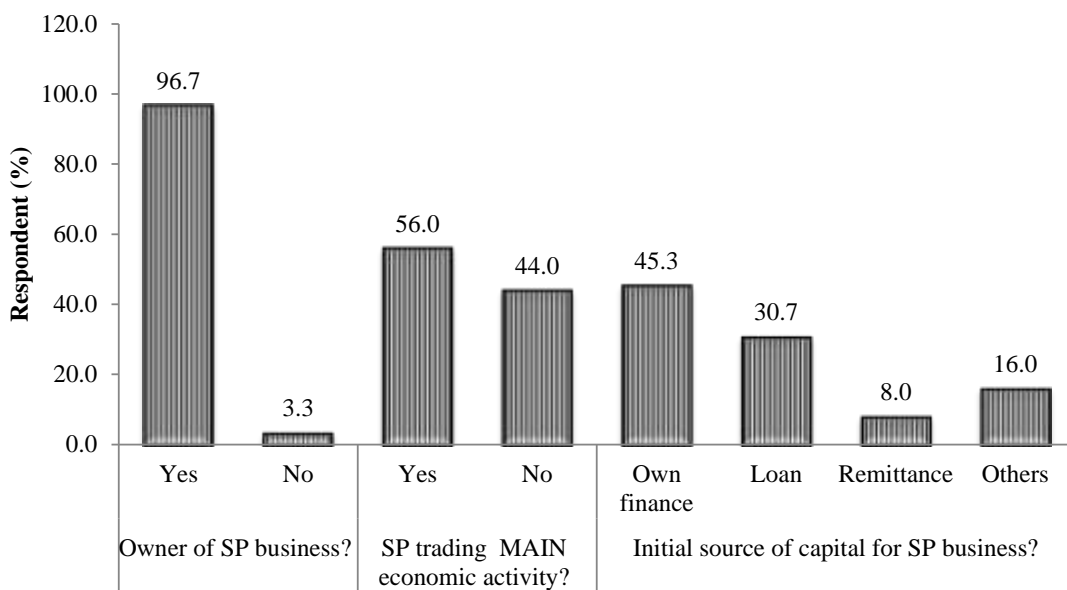


Figure 3. Socio-economic characteristics of sweet potato activities.

in Bo (17.0%) district. These results showed that, majority of the respondents are not literate enough to effectively keep records of their sweet potato marketing business transactions.

General sweet potato trading activities

The majority (96.7%) of the traders interviewed were the

owners of the sweet potato business and 56.0% of them do sweet potato trading as their main economic activity. Own/self-financing (45.3%), loan (30.7%), other sources (16.0%) and remittances (8.0%) were the initial source of capital for their sweet potato trading activities (Figure 3). The bulk of the traders contacted are sweet potato roots trader (98.0%) and the remaining 2.0% may either sell the leaves or other sweet potato products such as sweet potato chips, pourage etc. (Figure 4).

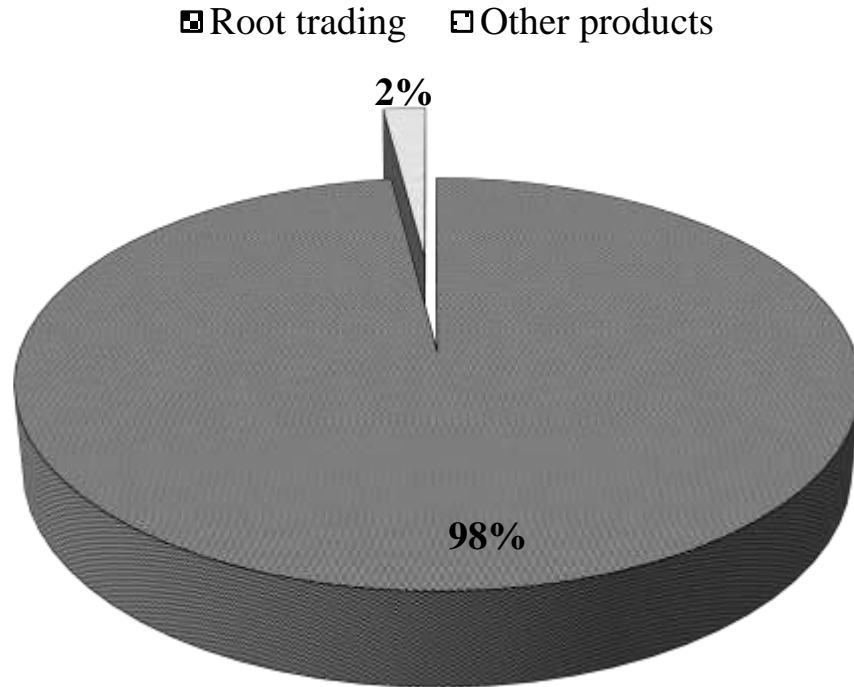
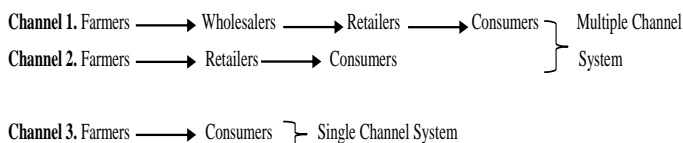


Figure 4. Sweet potato produce/product trading.

Sweet potato roots distributional channels in Sierra Leone

The marketing channel for sweet potato is shown in Figure 5. The distribution or marketing of sweet potato operates through the activities of many actors in both rural and urban markets. The results of the study showed that, the sweet potato marketing channels comprise two key channels such as the single and the multi-stage channel systems. 86.7% of respondents are retailers; 11.3% are wholesalers and the remaining 2.0% for other traders (Middlemen/SMEs processors). 52.2% of traders buy directly from farmers, 29.0% from wholesalers/aggregators, 9.4% produce the sweet potato sold (own farm) and 9.4% from other sources. The traders engaged in sweet potato trading sell their products in daily village/town markets followed by periodic markets, roadside markets, own farm/gardens and street markets. The major share of the sweet potato business in Sierra Leone is being controlled by retailers (88.4%) and wholesaler (10.9%) followed by other market intermediaries, with 0.7%. It is evident from the study that retailers and wholesalers are important players in the sweet potato marketing chain.



Marketing margins and net profits of sweet potato traders

Table 3 shows the buying cost, transaction cost and the total revenue generated from the sale of sweet potato roots for the various districts and the study area. The total average revenue from the selling of 50 kg bag of sweet potato roots in the study area was Le 71,198. The highest revenue generated from the sales of 1 bag of sweet potato roots was in the Western area (Le 81,667), followed by Kenema (76,310), Moyamba (74,000), Bo (68,900) and Bombali (55,283). The average total cost in sweet potato root trading in the study area was Le 59,152.

The least cost for buying 50 kg bag and other transaction cost was in Bombali (Le 40,567) followed by Kenema (Le 62,179), Bo (Le 62,678), Moyamba (Le 62,767) and Western Area (Le 67,419). Since, the least transaction costs and revenue were incurred in Bombali, therefore, the highest net profit from the sale of 1 kg of sweet potato roots was obtained from that district. The higher profit from sweet potato root trading in Bombali may be due to the fact that traders got lower prices due to the large scale of production of sweet potato roots. The next district with highest net profit was Western area (Le 14,248) followed by Kenema (Le 14,131), Moyamba (Le 11,233) and Bo (Le 6,222). The average net profit in the study area was Le 12,046 (Table 3). The benefit-cost ratio of sweet potato root trading in each of the districts and overall was greater than one, which indicates that

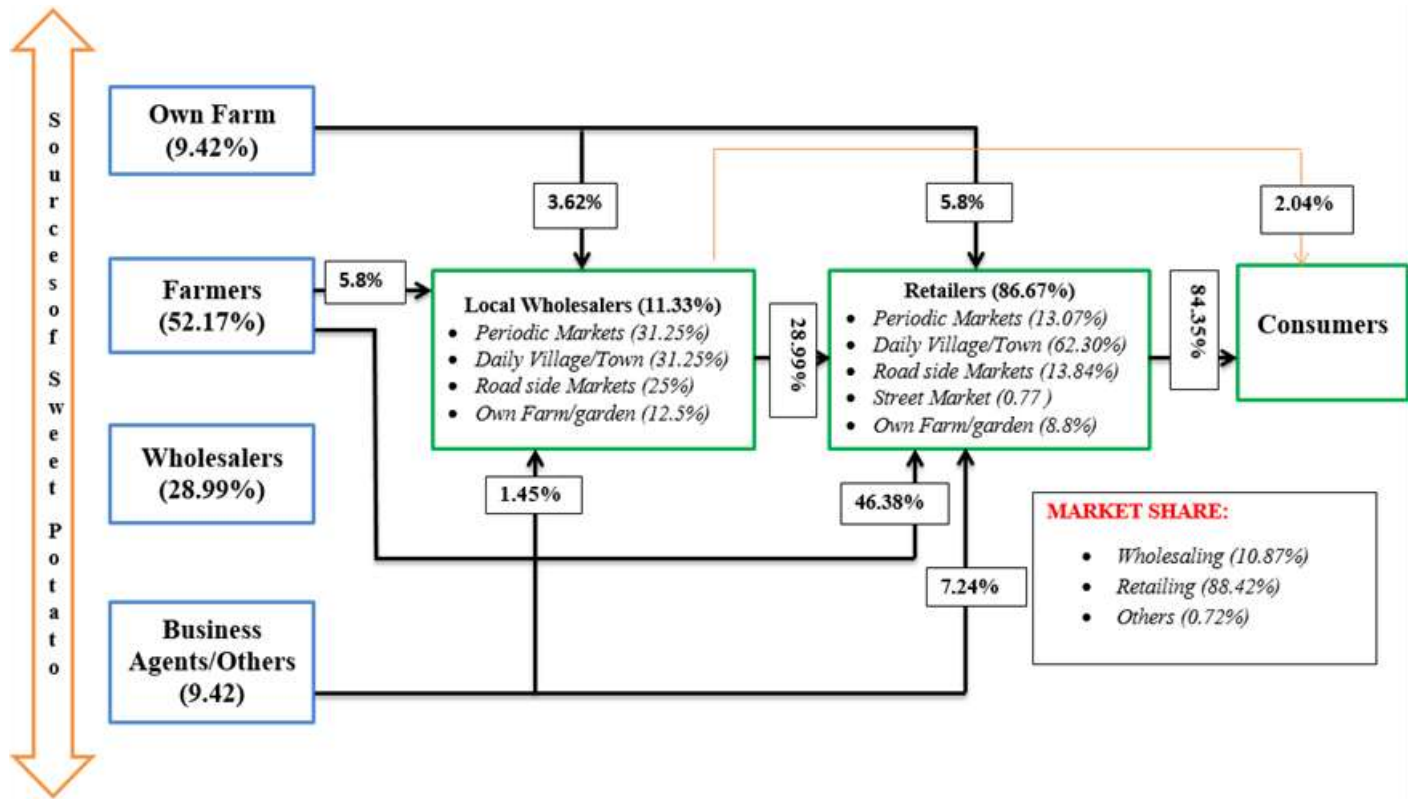


Figure 5. Sweet potato roots distribution channels in Sierra Leone. Source: Survey Data (2018).

sweet potato roots trading business is profitable. That is, for every Le 1.00 invested in sweet potato root trading; there is a gain of Le 0.36 in Bombali, Le0.23 in Kenema, Le 0.21 in the Western Area, Le 0.18 in Moyamba, Le 0.10 in Bo district and Le 0.20 in the study area. This clearly shows that sweet potato root trading is a profitable business venture in Sierra Leone (Table 3).

Drivers and barriers of sweet potato trading in Sierra Leone

Table 4 illustrates a SWOT analysis of the factors considered by traders which influence sweet potato root trading. The strengths and weaknesses are characteristics intrinsic to the trader, whilst opportunities and threats relate to external factors that condition the balance between the strengths and weaknesses.

Drivers (strengths and opportunities)

From Table 4, the three major strengths of sweet potato root traders computed were easy access to smaller market (32.8%) facilities, having high business techniques (23.8%) and storage facilities (23.2%). The

three major opportunities for sweet potato root trading were the availability of sweet potato roots (28.8%), easy access to markets for buying sweet potato roots (24.4%) and high demand for sweet potato roots (19.4%).

Barriers (Weaknesses and threats)

The three major weaknesses to sweet potato root trading were lack of finance and credit facilities (44.6%), low availability of sweet potato roots during certain period of the year (26.8%) and lack of big market facilities (16.7%). The three major threats to sweet potato root trading were no external funding for sweet potato trading activities (27.0%), high transportation costs (22.0%) and high taxation and market dues (18.1%) (Table 4).

DISCUSSION

From Table 2, women dominate the sweet potato trading. The dominance of women in sweet potato marketing is traditionally believed that, sweet potato is a female-crop. However, men are more engaged in production activities (land preparation and harvesting) than marketing. This result is consistent with Natson et al. (2017), Ocholi et

Table 3. Marketing margins and net profits of sweet potato traders.

Variable	Moyamba	Bo	Bombali	Western area	Kenema	Study area
	Mean	Mean	Mean	Mean	Mean	Mean
Cost for 50 kg bag (Le)						
Buying price of sweet potato	47,100	48,679	31,019	53,448	51,154	46,382
Transportation cost for roots	8,464	7,000	3,357	6,400	3,963	5,874
Market dues for roots	683	600	605	600	680	634
Storage	1,233	1,174	1,061	1,814	1,147	1,340
Packaging	2,605	1,917	3,310	3,143	3,172	2,871
Other Costs	2,682	3,308	1,215	2,014	2,063	2,051
Total transaction costs	62,767	62,678	40,567	67,419	62,179	59,152
Sale for 50 kg bag (Le)						
Total revenue from sales	74,000	68,900	55,283	81,667	76,310	71,198
Profit and margins						
Gross profit	26,900	20,221	24,264	28,219	25,156	24,816
Net profit	11,233	6,222	14,716	14,248	14,131	12,046
Gross Marketing Margin	36.35	29.35	43.89	34.55	32.97	34.85
Net Marketing Margin	15.18	9.03	26.62	17.45	18.52	16.92
Benefit cost ratio (BCR)	1.18	1.10	1.36	1.21	1.23	1.20

Source: Survey data (2018).

Table 4. Drivers and barriers to sweet potato root trading in the study area.

Attribute	Freq.	%	Attributes	Freq.	%
Drivers					
Strengths			Opportunities		
Access to smaller market	106	32.8	Availability of SP roots	111	28.8
High business techniques	77	23.8	Easy access to markets for buying	94	24.4
Have storage facilities	75	23.2	High demand for SP products	75	19.4
Access to finance and credit	47	14.6	Availability of good road network	38	9.8
Member of a traders organisation	18	5.6	Favourable government policy	36	9.3
			Availability of financial institutions	32	8.3
Barriers					
Weaknesses			Threats		
Lack of finance and credit	120	44.6	No external funding	118	27.0
Low availability of SP roots	72	26.8	High transportation cost	96	22.0
Lack of big market facilities	45	16.7	High taxation / market dues	79	18.1
Lack of storage facilities	32	11.9	Theft	73	16.7
			Market diversity and competition	61	14.0
			Natural disaster	10	2.3

Source: Survey data (2018).

al. (2017), Fadipe et al. (2015) and Asogwa et al. (2014), who reported similar pattern that, majority of respondents (wholesalers and retailers) were females engaged in cassava and sweet potato marketing. The market is also dominated by married couples (Moyamba: 80%, Bo: 53.3%, Bombali: 73.3%, Western Area: 73.3%, Kenema:

70.0% married). This justifies the economic behaviour and rationality in decision they always make towards their sweet potato trading. This is supported from the focus group discussion results and also reinforced by the results of Natson et al., (2017) and Ocholiali et al. (2017). Natson et al. (2017) states that, women have assumed

the role of economic activity to help support their family.

The results of educational status showed that, majority (54.2%) of the sweet potato traders at least has some form of formal education but the level of formal education is very low to effectively help them take and keep records of their sweet potato marketing transactions. This is because, bulk (27.5%) of the traders stop at early elementary school (Class 1 to 6). This result is supported by International Growth Centre policy brief (2018) which indicates that, the educational status of traders in Sierra Leone crossing the official borders, more than half of exporters (54%) and importers (56%) completed primary education. Natson et al. (2017) reported the same educational status but holds this view; by implication, most of the traders at least had the required skill to keep record of activities and to tap into modern trends and existing market prices to make reasonable profit. This result is also in agreement with the results of Ocholiali et al. (2017) (Figure 2).

From Figures 3 and 4, majority (96.7%) of the sweet potato traders interviewed were the owners of the business. Sweet potato trading is the main economic activity (56.0%); their initial source of capital is mostly from own source or family funding (45.3%) and from informal loan (30.7%) and almost 98.0% of respondents interviewed were sweet potato root traders. Therefore, the ownership of the business, sweet potato trading as their main economic activity and the initial source of capital coming from them show how committed are they during their sweet potato trading activity. The results also revealed the nature of sweet potato trading as a petty trading that does not demand huge initial capital for start-up. This finding is in consonance with earlier findings by Ocholiali et al. (2017) and Abah et al. (2015). Ocholiali et al. (2017) found that, majority of sweet potato traders in Benue State, Nigeria depend on personal or family funding for their business.

From Figure 5, the marketing channel shows the different (alternate) routes through which sweet potato passes from the producer to the final consumer. The sweet potato marketing channels in the study area are made up of single and multi-stage channels. The single channel consists of the flow of sweet potato products from the producer to the consumer directly without any intermediary. The multi-stage channel system consists of middle-men (intermediaries) before it gets to the final consumer. The multi-stage channel system is made up of the sweet potato farmers and different categories of traders (wholesalers, retailers and aggregators). All these categories of intermediaries are in mutual agreement because the producer can decide to sell directly to the wholesalers and retailer (Tewe et al., 2003). In Sierra Leone, it is difficult to ascertain who is a wholesaler or retailer in the market. This is because some distributors are engaged in both wholesaling and retailing activities at the same time and place. However, categorization of wholesalers and retailers is based on the quantity of roots

sold and more pronounced activity a wholesaler or retailer does. The implication of multi-stage system is that, as commodities pass through many intermediaries, it tends to increase marketing costs which will be borne by the consumers.

The results from Table 3 show that, the marketing margin is very high (Le 24,816) per selling of 50 kg bag of sweet potato with a net profit (Le 12,046), Gross marketing margin (34.85), Net marketing margin (16.92) and a benefit cost ratio of greater than 1 (BCR>1). This clearly reveals how lucrative and profitable sweet potato trading is in Sierra Leone. Ocholiali et al. (2017) and Natson et al. (2017)'s findings support the above statement by saying, sweet potato trading is a profitable and a lucrative business venture that is worth investing in.

From Table 4, combining those strengths and opportunities, the three major drivers to sweet potato root trading were: traders having access to market and storage facilities for sweet potato root trading, sweet potato roots are always available in the markets and high demand for sweet potato roots in the market. Combining those weakness and opportunities, the three major barriers to sweet potato root trading were: lack of financial support to trader for sweet potato root trading, low availability of sweet potato roots during certain periods of the year and high transportation costs from buying locations to the market. Ocholiali et al. (2017), Achike and Anzaku (2010) and Fawole (2007) also mentioned lack of financial support or low initial investment, high transportation cost as key constraint towards marketing of agricultural produce especially for roots and tubers.

CONCLUSION AND RECOMMENDATIONS

Sweet potato root is the major product of sweet potato sold in the various markets (on-farm, daily village or town, road side and periodic) in Sierra Leone. The trade is more dominated by women and is very profitable. The profitability is with regards to income levels generated in marketing. Sweet potato trading investment has a net positive return. After the calculation of the cost benefits analysis, the benefit-cost ratio of sweet potato root trading in each of the districts was greater than one, which indicates that sweet potato roots trading business is profitable. The revenue generated in the sale of one bag of sweet potato is high. That is, an average of 20% profit is realised from the 1 bag (50 kg) that is bought and sold and the highest profit was realised in Bombali District.

The sweet potato marketing channels in Sierra Leone are made up of single and multi-stage channels. The single channel consists of the flow of sweet potato products from the producer to the consumer directly without any intermediary. The multi-stage channel system consists of middle men or intermediaries (Wholesalers,

retailers and other agents) before it get to the final consumer. The major drivers to sweet potato root trading are traders having access to market and storage facilities for sweet potato root trading, sweet potato roots are always available in the small markets and the high demand for sweet potato roots in the market. The major barriers are lack of financial support to trader for sweet potato root trading, low availability of sweet potato roots during certain periods of the year and the high transportation costs from buying locations to the market. The study also revealed considerable numbers of factors that militate against an efficient marketing system of the crop. Based on the findings of this study, it is recommended that:

- (i) Sweet potato marketers should form groups for them to build a unified front for higher bargaining power in price and also to obtain loans from financial institutions easily to increase their initial capital base. Loans will be easily acquired from financial institutions without bottlenecks in form of groups than individually. Innovation Platforms (IP) involving all actors in the sweet potato value chain should be encouraged to allow actors take advantage of various opportunities in the areas of easy access to inputs at lower cost and guaranteed access to financial support.
- (ii) To overcome those barriers towards sweet potato trading, government should ensure a reliable pricing and market policy (government regulates the commodity prices directly depending on world market conditions and welfare of the traders) and also enact policies that would enable traders to easily access credit facilities for trading of agricultural commodities, support farmers with agro inputs, equipment and machinery to increase sweet potato production throughout the year and improve on the road network in order to facilitate easy and affordable means transportation of agricultural produce from the farm to market.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Status of pests and diseases of sorghum and their management practices by “Fadama” III participating farmers in Abuja, Nigeria

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A diagnostic survey was carried out at the end of 2018 and early 2019 to assess the status of sorghum pests, diseases and their management strategies by the “Fadama” III participating farmers in the Federal Capital Territory (FCT), Abuja, Nigeria. Data were collected from the 28 production clusters in 10 Fadama Development Areas in the six Area Councils. Instruments used were semi-structured interview, farm visits and the diagnosis of collected specimens from infested and diseased sorghum. The results indicated that up to 97.95% of the farmers had one form of formal education. On sorghum farms, corn rootworms (*Diabrotica virgifera*), *Striga* spp. weed and straying cattle were the major pests encountered. The incidence of *Striga* weed was 20.97%, while that of anthracnose disease was 76.84% though often left uncontrolled. Indigenous knowledge used for managing sorghum pests included field spraying with goat faeces slurry and placement of neem and *Blumea* leaves in corn granaries. Sorghum seeds were locally dressed with berry bark exudate, neem extract + pepper pre-planting. Due to the high severity of anthracnose on sorghum in the FCT, Abuja, there is need to embrace integrated disease management practices against this endemic disease. Routine monitoring of sorghum pests and disease prevalence, incidence and severity at different growth stages and implementation of sorghum pests management plan emanating from this study across Fadama Development Areas in Guinea Savannah agro-ecological zone is expected to enable the attainment of sustainable sorghum productivity.

Key words: Abuja-Nigeria, Fadama, incidence, insects, Integrated Pest Management (IPM), sorghum, weeds.

INTRODUCTION

The National Fadama Project in Nigeria is financed by World Bank, the African Development Bank and the Nigerian Government (Gourichon, 2013; Ani, 2014). This agricultural development project has an intention of increasing the incomes of *Fadama* land users on a

sustainable basis and reduce their poverty level (Ogunlela and Ogunlela, 2008; Afolabi, 2010; Effiong and Asikong, 2013). The project is designed to be a participatory and socially inclusive approach that empowers the farmers, to take control of and manage

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their resources for their own development (NFDO, 2007; Ani, 2014).

One of the mandate crops by the FCT Fadama farmers under the Fadama III Additional Financing (AF I) is Sorghum [*Sorghum bicolor* (L.) Moench; Family: Poaceae]. They are often produced in the Savannah including the periphery of expanse of Fadama lands and processed into sorghum value added products in different forms across the territory (Pande et al., 2008). The interest by the Project in promoting sustainable sorghum production through adequate protection against pests and diseases in Nigeria is not unconnected with sorghum immense economic and comparative advantages. Sorghum is used for food (as grain and in sorghum syrup or "sorghum molasses"), fodder, the production of alcoholic beverages, and biofuels (Adegbola et al., 2013). However, some important challenges to sorghum production are insect pests, diseases and weeds and impact of harmful chemicals that threaten the environment and human health alike (Chunshan et al., 2011). Pests of sorghum include insects, rodents, nematodes, birds and any form of plant, animal or any pathogens that adversely affect the crop and its products, and people (Abrol, 2013).

In order to proffer appropriate management options of pest and diseases of sorghum and to enable optimum yield, there is need to determine the status of pests and diseases of the crop. Thus the objectives of the study are to: (i) evaluate the knowledge and awareness of participating farmers about sorghum pests and diseases. (ii) identify and determine the incidence of insect pests, diseases and weeds build-up on sorghum farms in the FCT, Abuja (iii) assess the management practices of pest and disease on sorghum among the participating farmers and (iv) recommend effective mitigation measures based on the IPM diagnostic survey of Fadama sites in the FCT, Abuja, Nigeria. The findings from this study are expected to be useful in decision making in future sorghum pest management planning and implementation.

MATERIALS AND METHODS

Study area

The study area is the Federal Capital Territory (FCT), Abuja in the North Central part of Nigeria. There are six Area Councils in the FCT, Abuja and the pest survey covered 10 Fadama Development Areas (FDA) as shown in Figure 1. The FCT has a land area of 8,000 km². It is bounded on the north by Kaduna State, the west by Niger State, the east and southeast by Nasarawa State and the southwest by Kogi State. It falls within latitudes 70 20' north of the Equator and Longitudes 60 45' and 70 39'.

Data collection

The study was carried out by survey through the instrument of flexible semi-structured interview survey. This was employed to elicit information on sorghum farming activities, awareness of pests

and diseases on sorghum farms and level of practice of Integrated Pest Management (IPM) by the respondents. A total of four hundred and eighty five questionnaires were purposively distributed by the assigned Fadama office facilitators to the respondents from 10 Fadama development areas in the six Area Councils. The number retrieved was 480 copies that is 48 questionnaires per development areas and used for data collation and analysis. Questionnaires prepared were test run and administered to randomly selected groups and clusters in the six Area councils namely Abaji, AMAC, Bwari, Gwagwalada, Kuje and Kwali. In addition, personal observation on sorghum field was employed. An accurate geo-referencing coordinate and mapping of sampling points or selected sites and area of mass infestation/infection were carried out between November – December 2018, using GPS MAP 76CSX, (2001) manufactured by Garmin International Inc. USA. Such GPS allowed for the visitation of the same location next time and can help to manage more persistent disease problems.

Insect pest collection and identification

For farm insect sample collection, live specimens were captured by using nets for flying insects. For other insects, a cup or margarine container was placed over the insects and allowed to crawl in. They were then safely picked up and covered with lid or paper towel. The insects caught were then immediately placed in ≥ 95% ethanol or rubbing alcohol (isopropyl). Each of them was labeled with date, location, and your name. They were then placed in freezer and stored at -20°C until ready for proper identification in the laboratory and insect museum in the Department of Crop Protection, Ahmadu Bello University, Zaria. The insects collected were classified into order using an on-line identification key or cereal insect pest identification manual. Microscope attached with a computer was also used to sort insects into morphospecies (Tuzun, 2010).

Sorghum disease assessment

Sorghum samples were assessed to check if they have disease, any abnormality such as discoloration, spots or holes on the leaf, if the plants are smaller than usual or if parts of the plant are dead, if the plant has holes, spots or discoloration in the stem or in the panicles/grains. Diseased samples were collected with sterile sharp knife and identified with hand lens and camera for taking close-up digital photos before being compared with crop diseases identification manual. Pests infested and diseased sorghum samples were collected from the sorghum farms by the engaged field technologists.

If symptoms or signs cannot provide enough specific or characteristic information to decide the cause of an infectious disease on sorghum, samples were taken to the laboratory for further tests to isolate and identify the causal agent. Equipment such as microscope, autoclave and identification manuals for cereal crop diseases and weed were used for confirmation (Federico et al., 2015).

Pest and disease incidence

Pest and disease incidence were visually rated on at least three spots in a farmer's field or store visited. Percentage incidence was calculated as the number of infected crop stand over the total number of crops stands sampled as indicated in formula (1) as used by Ogolla et al. (2019):

$$\text{Pest/disease incidence} = \frac{\text{number of infested /diseased plant} \times 100}{\text{total number of sampled plant}} \quad (1)$$

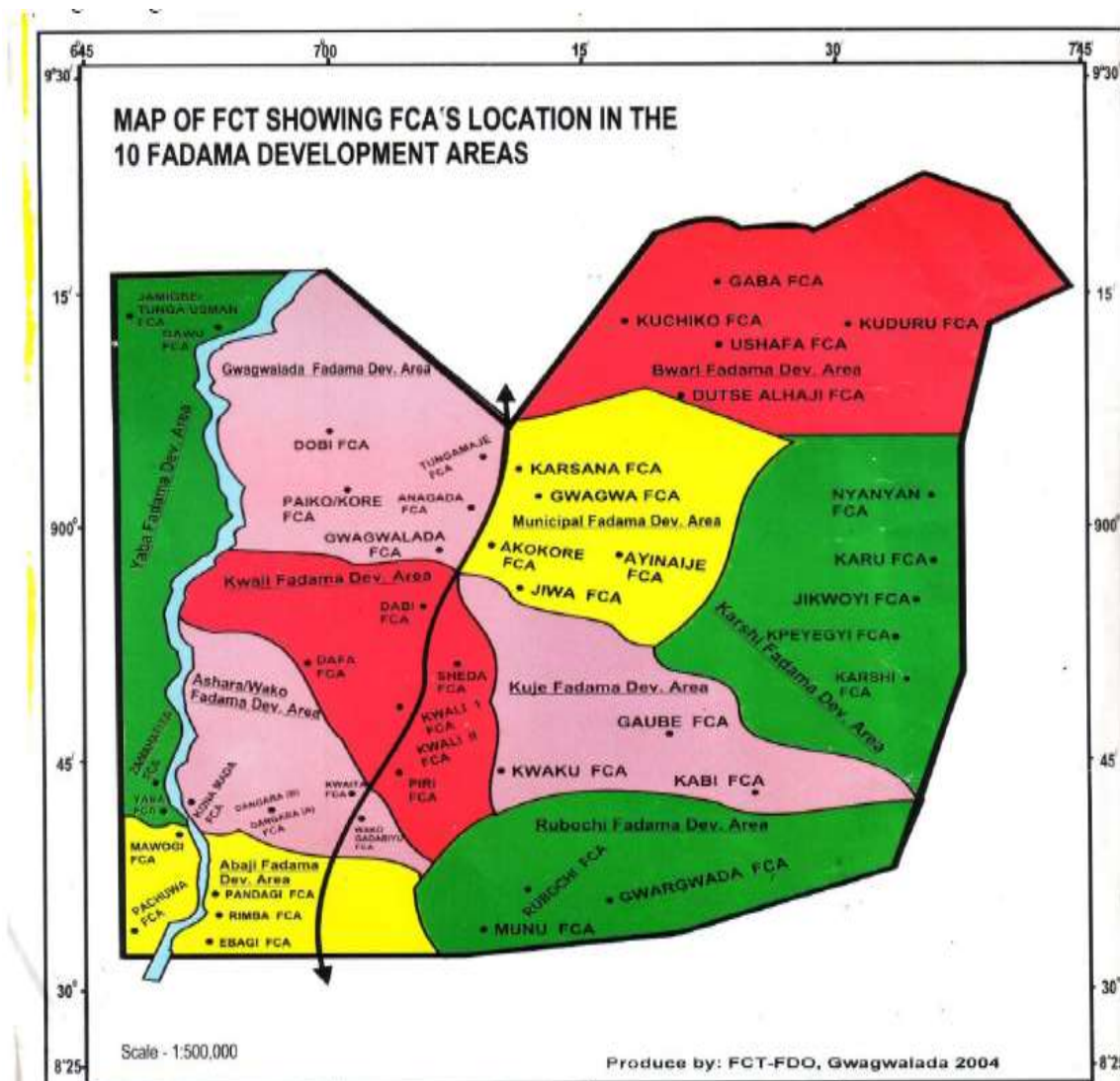


Figure 1. Map of FCT showing Fadama Development Areas within the Area Council.
Source: FCT Fadama.

Statistical analysis

Data obtained from retrieved questionnaires were coded and inputted into Microsoft excel (IBM SPSS version 20) and analysed using the Statistical Package for Social Sciences. Most results including observations on the pest and disease incidence were presented in frequency and percentages. The plates of major insect infested and disease infected specimens and weed specimens are shown.

RESULTS AND DISCUSSION

Socio-economic characteristic of respondents

Majority of the respondents - the sorghum farmers were males (93.18%), while the female was 6.82%. It was revealed that most of the production activities such as

ridging were carried out by the males while the planting and processing were mostly carried out by the female. Balogun et al. (2013) reported that there was a significant difference in all the activities performed by male compared to their female counterparts in Fadama Crop Production Project in Kwara State.

Most of the respondents were adults between 31 and 40 years (38.76%) with only 6.40% above 60 years old (Table 1). This indicated that most of the farmers that participated in sorghum production under the programme were in their active productive years. The age of the farmer according to Adewumi and Omotesho (2002) is expected to affect his productivity, output and the adoption of innovations in farming. Only about 12.05% of the respondents have informal education while higher groups had secondary education (26.50%) and tertiary education (24.17%) respectively. The attainment of any

Table 1. Socio-economic data of sorghum farmers in the FCT, Abuja.

Parameter	Frequency (%)
Age (year)	
21- 30	15.41
31-40	38.76
41-50	17.61
51- 60	11.95
51- 60	11.72
61- above	6.40
Level of education	
Informal	12.05
Quaranic	13.07
Primary	23.88
Secondary	26.50
Tertiary	24.17
Farm size/annum	
<1 Ha	38.32
1 – 3 Ha	43.23
>3 Ha	18.45

Table 2. Sorghum cropping practices in three of the area councils of the FCT.

Area council	Varieties of sorghum planted	Indigenous knowledge used in managing Sorghum pests	Major challenges	Common insecticide	Common herbicide
Bwari	Samsorg 47 local var. : <i>Zauna inuwa</i> , Samsorg 48	Early planting, trapping, wood ash,	Striga and goat weed; inadequate fertilizer	Mancozeb for seed dressing	Gramazone
Gwagwalada	Samsorg 47; Kaura	Catapult, gwaska + salt, scare crow; fencing in Ledi; Hyptis leaf, neem seed powder; occasional heating to rhombus to repel insect pest.	Bird pest (e.g. quela) Anthracnose disease; <i>Hyptis</i> spp weed	DDforce, coniz, use dichlorovous	Paraquat and glyphosate
Kuje	Samsorg 47 are red sorghum, black eye sorghum, sorghum short or long kaura Samsorg 58 and Samsorg 53.	Goat/cow faeces, trap, locust bean extract, dialogue with herdsmen, lime water, salt, tobacco powder and seed coating with bitter lemon bitter lemon, crop rotation and ordeal tree bark powder, timely planted, early weeding, crop rotation,	<i>Wutawuta</i> parasitic weed (<i>Striga</i> spp) monkey, weaver bird, bad road e.g. in Fogbe and Shitumu villages; high cost of hiring tractor, labour; smut diseases	Neem, wood ash,	Thrips; Grain borer

type of formal education is expected to have a favourable attitude towards the adoption of agricultural innovations (Agwu, 2004; The Agriculture Promotion Policy, 2020). Majority of the sorghum farmers -43.23%, cultivate between 1 and 3 ha annually, while only 18.45% have over 3 ha. This was slightly lower than the farm size cultivated by the Fadama farmers in Orire Local Government Area of Oyo State-Nigeria, where about 40% of them farmed between 1.61 and 3.2 ha annually (Akangbe et al., 2012).

Sorghum cropping practices in the FCT

Higher percentage of the farmers planted improved sorghum varieties (92.50%) while the rest 7.50% planted local varieties (Table 2). Major varieties of sorghum planted were Samsorg 47, 48, 53, 58 and *kaura inuwa* and this were mostly planted in the month of July every year. Up to 93.17% of the respondents sourced their Fadama programme and just 6.83% from other sources. Majority of the farmers (67.56%) do plant their sorghum

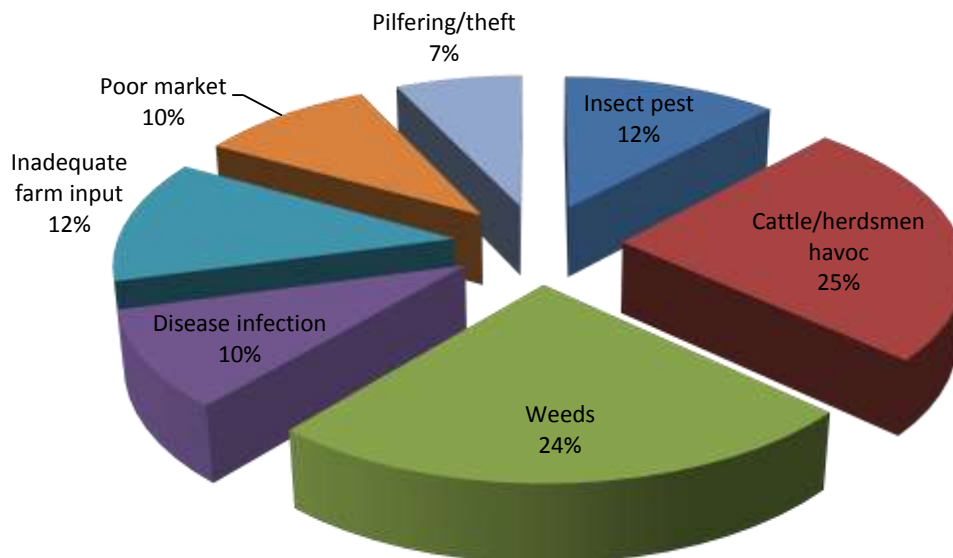


Figure 2. Rating of challenges to sorghum production by the FCT Sorghum farmers. Source: Fadama Farm Survey (2019).

in July (Table 2). It was indicated that only 34.73% of the farmers cropped their sorghum farm from fallowed field in the previous year. As high as 65.60% of the farmers planted sorghum in the previous year on their present farm. This implied that most sorghum farms were cropped in the previous years. Weaver and quela bird was serious pest on sorghum farms located near a river or a forest. The high prevalence of anthracnose and leaf blight diseases and midge insect pest often led to low panicle formation and reduced yield but most farmers were not aware of this. This might be due to lack of awareness among farmers and inadequate extension agents (Sylla et al., 2019).

Indigenous knowledge used for managing sorghum pests included coating or spraying of leaves with goat faeces slurry on the field and use of neem and *Blumea* leaves in corn granaries. Sorghum seeds were locally dressed with wood ashes, *fukai* and *gwaska* extracts, Christmas berry bark exudate, neem extract + pepper before planting; also tobacco powder and ordeal tree leaf/bark powder were used for seed coating. Striga weeds were locally managed with locust bean extract, delayed planting and crop rotation and intercropping sorghum with millet. The efficacy, development and usage of indigenous knowledge of crop and diseases management should be encouraged and their efficacies confirmed.

Challenges to sorghum production

Majority (47.50%) of the respondent farmers considered cattle/herdsmen menace as the most problematic pests on their farm (Figure 2). Weeds were rated first by

46.67% of the respondents. There is no doubt that weeds are important problems in crop production fields and the respondents were knowledgeable about the adverse effects of weeds as reported by Banjo et al. (2010) and Abang et al. (2014). Other problems including diseases of sorghum were rated first by only 18.33%. This perception showed that diseases such as sorghum anthracnose, despite their pathological importance, are seldom recognized as so by the farmers, possibly due to ignorance.

Pests, diseases and weeds of sorghum in the FCT

The incidence of pests, diseases and weeds and mean % yield reduction associated with sorghum is as shown in Tables 3 to 5. In terms of pest identification, all farmers in most sites were able to identify stem borer and shoot fly larvae when shown a picture. Although farmers in Yaba Abuja could identify the "small insects" that fly around the panicle during flowering and also could easily identify the symptoms of midge damage, they could not differentiate the two.

Sorghum stalk borer had the highest incidence of 38.91%. The farmers could not actually quantify the mean percentage crop yield reduction of these insect pests but indicated that *Sitophilus graminea* can cause up to 57.11% reduction on the grains if not well managed. They in addition revealed that a mean of 59.22% yield reduction could result from cattle/goat attack. The mean incidence of anthracnose (foliar, head, root and stalk rot) was 76.84% but the mean percentage yield reduction is uncertain. This is on the high side and its management requires urgent attention. Striga (witch weed) infestation

Table 3. Incidence and mean % yield reduction by insect pests associated with sorghum on FCT farm.

S/N	Common name	Causal genus	Prevalence in (In 6 AC)	Incidence (%)	Mean % yield reduction
1	Caterpillars	<i>Helicoverpa armigera</i>	4/6	18.85	59.09
2	Midge (cause blast on panicle)	<i>Stenodiplosis sorghicola</i>	3/6	6.25	Don't know
3	Sorghum corn borer	<i>Chilo</i> spp	5/6	38.91	"
4	Sorghum weevil	<i>Sitophilus gramineae</i>	6/6	24.55	57.11

Table 4. Incidence of other pests associated with sorghum on the field.

Common name	Class/Genus	Prevalence in 6 AC	Incidence (%)	Mean % yield reduction
Birds (bush fowl, weavers)	Aves	2/6	26.76	32.41
Cattle/goat	<i>Bos/Capra</i> spp	4/6	24.45	59.22

Table 5. Incidence and mean percentage yield reduction of diseases associated with sorghum.

Causal organism	Common name	Causal Genus	Prevalence (in 6 AC)	Incidence (%)	Mean % yield reduction
Fungi	Anthraxnose (foliar, head, root and stalk rot)	<i>Colletotrichum</i> spp.	6/6	76.84	Don't know
	Brown leaf spot	<i>Cercosporidium</i> spp.	3/6	20.99	"
	Kernel/grain smut	<i>Sporisorium sorghii</i>	2/6	5.58	1.01
	Leaf rust	<i>Puccinia purpurea</i>	3/6	2.05	Don't know
	Loose kernel smut	<i>Sporisorium cruentum</i>	2/6	1.75	1.14
	Head smut	<i>Sporisorium reiliana</i>	2/6	0.20	0.49
Virus	Yellow sorghum stunt	Yellow sorghum stunt phytoplasma	1/6	0.99	0.33

(Plate 9) was a major problem on sorghum farm in the FCT. The mean incidence is as high as 25.97% and could cause a mean percentage yield reduction of 87.32%. Striga has growth inhibitory activity on *Sorghum* (Rana and Rana, 2016; Akomolafe et al., 2018). The results thus indicated that the extension agents have shallow knowledge of identifying sorghum pests and diseases, thus needed to be retrained.

Major insect pests and diseases identified on sorghum in the FCT

Some common insect pests and samples of sorghum with diseased symptoms in the FCT are shown in the infographics below. Army worm (Plate 1) is sheltered in the axils of plants and their larvae feed and damage young plants. Faecal pellets, damaged and chewed leaf margins were signs of damage. Ching bug (Plate 2) resides in grassy weeds and moves to seedling plants. They attach sorghum and feed on the stem and large leaf veins and sometimes lead to wilting and stunted growth and can kill seedling. The high prevalence of anthracnose

disease and midge insect pest often lead to poor panicle formation and low yield. This is associated with lack of awareness among farmers and inadequate extension agents.

Moth (*Helicoverpa armigera*) larvae (Plate 3) do feed on the pollen sacs in the flower and feed on developing seeds. The corn root worm - (*Diabrotica virgifera*) (Plate 4) often feeds below the soil line, can cause wilting of seedling and lead to retard growth of the plant. The sorghum midge - *Stenodiplosis sorghicola* (Plate 5) eggs hatch and feed on immature seed, and could hamper development of seed kernel. Stink bugs (*Blissus leucopterus*) were found on developing sorghum ear on Nomadic farm in Bwari (Plate 6). Anthracnose of sorghum (Plate 7) is caused by *Colletotrichum graminicola* and has small, circular to elliptical spots on leaves and leaf sheaths. Older spots have greyish or straw coloured centres with reddish borders and bear black acervuli. The mid-rib infection occurs as elliptical to elongate, discoloured lesions which may coalesce to cover the entire length of the midrib. The use of host plant resistance and crop residue management on the farm is recommended (Pande et al., 2008). Plate 8 shows



Plate 1. Army worm (*Sporodera armygera*) found on sorghum leaf in Ledi Dobi, Gwagwalada.



Plate 3. *Helicoverpa armigera* found on sorghum farm in Pandagi, Abaji.



Plate 2. Chinch bug (*Blissus leocopterus*) found in Sorghum seedling in Bwari, Bwari Area council.



Plate 4. Root worms (*Diabrotica virgifera*) in sorghum root in Lafia Yaba, Abaji.

a loose smut of sorghum on a farm in Sheda Kwali Abuja; it is also found in Gwako Gwagwalada Abuja. The grains are replaced with black powdery materials (sori), while Plate 9 depicts *Striga hermonthica* flowering on Sorghum in Kwali FCT, Abuja. Plate 10 shows the rust disease of sorghum where rust pustules (uredosori) appear on both surfaces of leaf as purplish spots. The pustules may also occur on the leaf sheaths and on the stalks of inflorescence.

Status of integrated pest management (IPM) of sorghum in the FCT

Integrated Pest Management (IPM) has emerged as a way towards maintaining or increasing crop productivity without over-reliance on synthetic chemical pesticides (Aktar et al., 2009; Abrol, 2013). Out of the nine



Plate 5. Sorghum midge (*Stenodiplosis sorghicola*).



Plate 6. Stink bugs (*Blissus leucopterus*) found on developing sorghum ear on farm in Bwari.

management strategies indicated by the respondents, only the management of sorghum seeds/grains insect pest had high awareness with about 71% adopters while none of them was aware of management of the leaf blight and anthracnose diseases (Tables 6 and 7). Anthracnose and leaf blight diseases were the common diseases of sorghum in the FCT, but most farmers left such disease uncontrolled either due to ignorance or due to their cost



Plate 7. Anthracnose of sorghum on a farm in Paiko kore, Gwagwalada.



Plate 8. Loose smut of sorghum on a farm in Sheda Kwali Abuja also found in Gwako Gwagwalada Abuja the grains are replaced with black powdery materials (sori).

implication. In order to appropriately recommend pest management practices on the field or in the store, a well detailed information about farmers' awareness and management strategy of pests and diseases is necessary in fashioning more programmes that would aid the actualization of the objectives of the Fadama III Programme (Balogun, 2013).

Smut diseases in sorghum could be managed by chemical seed treatment with systemic fungicide, sowing of clean and healthy seeds, preventing the use of fields with previous infection / rotation with non-host crops and where practicable collect and destroy smutted heads before spores scatter to minimize spread (Agrios, 2005; Wagari, 2019). Others are by avoiding sowing seeds from infected field and using of resistant varieties. Striga weed



Plate 9. *Striga hermonthica* flowering on Sorghum in Kwali FCT, Abuja.



Plate 10. Rust disease of sorghum in Yangoji, Kwali.

on sorghum farm could be managed by the use of resistant varieties, crop rotations, weeding, raising the fertility of soils and the use of trap crops (Akomolafe et al., 2018).

In general, a four-step approach to IPM for sorghum protection is advocated. Firstly, action thresholds should be set at the point at which infestation by pests requires action. This involves a level of understanding about the

Table 6. Incidence and mean percentage yield reduction of major weeds/ alternative weed host associated with sorghum field.

Common name	Prevalence (in 6 AC)	Incidence (%)	Mean % yield reduction
Witch weed (<i>Striga</i> spp.)	-	25.97	87.32
Pig weed (<i>Boerhavia diffusa</i>)	-	15.13	Do not know
Wire grass (<i>Sporobolus diander</i>)	-	8.06	Do not know
Goat weed (<i>Agerantum conizoides</i>)	-	9.12	Do not know
Sedge (<i>Cyperus</i> spp.)	-	8.58	26.11

Table 7. Management status of pests and diseases of sorghum by the FCT farmers.

S/N	Management strategy	Level of awareness	% of adopters	Constraints
1	Rotate crops	Moderate	51	-
2	Select hybrid seeds for planting	Low	15	Ignorance, unaffordable
3	Maintain soil fertility	Moderate	23	Costly fertilizer
4	Early planting	Moderate	42	-
5	Bury previous-crop residue/clean weeding	Moderate	49	Cost of labour
6	Control field insect pests	Very low	10	Cost of insecticide,
7	Manage blight/smud diseases	None	0	Ignorance
	Manage anthracnose disease	None	0	Ignorance
8	Management of Striga on the farm	Low	12	Ignorance
9	Manage of pest of sorghum grains in the store	High	71	Laborious, costly

size of an infestation and at which point crop damage becomes a problem. Secondly, pests should be monitored and identified, to ascertain when levels reach action thresholds and to account for natural enemies. The third step of IPM is cultural methods such as diversification or planting pest-resistant crop varieties, use of disease-free seed and adoption of good practices in the field, such as removal of infected material that could carry the problem over to the next crop (Plate 11). Lastly, is the control through targeted use of pesticides or mechanical means may be required if pest numbers reach action thresholds and less invasive methods are not working or available.

CONCLUSION AND RECOMMENDATIONS

There was indication that the activities of the agricultural extension agents with respect to sorghum crop protection was poor and indeed necessary within the study area in order to educate the farmers on best management practices of the crop pest and diseases. Implementation of sorghum pests management plan emanating from this study is expected to improve the capacity of the benefitting Fadama groups and clusters and FCT farmers and enable the attainment of sustainable crop productivity.

Based on the outcome of this study, it is recommended

that routine monitoring of sorghum pests and disease prevalence, incidence and severity at different growth stages across Fadama Development Areas in Guinea Savannah agro-ecological zone is necessary. This is in order to obtain detailed and valid result that can serve as basis for management action to ensure effective sorghum pest and disease management.

Farmers are expected to seek help from an extension worker or an expert in crop protectionist as soon as they see any signs of pest or disease symptoms on their farms. Due to the high severity of anthracnose on sorghum in the FCT, Abuja, there is need to declare a state of emergency toward protecting the crop from this endemic disease.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Plate 11. Sorghum leaf blight on farm in Sheda Kwali Abuja.

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