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Farmers' perception on severity, crop loss and management practices of variegated grasshopper (*Zonocerus variegatus* L.) on cassava (*Manihot esculenta* Crantz) in Sierra Leone

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Abstract

Farmers' perception on the severity and management practices on cassava has not been fully investigated particularly across agro-ecologies in Sierra Leone. This study assessed the perception of smallholder cassava farmers on the severity of *Z. variegatus* L., its impacts on yield and indigenous coping management practices utilized to mitigate the infestation of grasshoppers in their cassava farms. The population of the study comprised 300 cassava farmers sampled from the north, south and eastern provinces of Sierra Leone. The study involved questionnaire research instrument administered to smallholder farmers who were farming for household consumption, those producing for sale and household consumption and those who were mainly producing for sale because their primary goal was to produce for the market. Findings revealed that farmers had perceived abilities about agro-ecological distribution of grasshoppers, making them to be familiar with cassava crop damage severity pattern and easy identification. Farmers have ability to recognize and identify adult grasshoppers, and part(s) of cassava mostly affected by grasshoppers. Cassava leaves and stems are destroyed by the pest during either preferential feeding or as a result of 'choice, no choice feeding'. The study established that smallholder farmers have perceived abilities to identify damage symptoms, stage(s) in the life cycle of the pest that is/are more destructive leading to crop losses and utilization of best practices to mitigate grasshopper infestation on cassava that could be exploited for increased production, management and conservation of cassava genetic resources. Moreover, 52.3% of variation in extent of crop loss by grasshopper infestation is attributable to life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers, cassava variety preference by grasshoppers and the best practices that contribute to increased cassava productivity.

Keywords: Cassava; Grasshopper; Severity; Farmers' Perception; Management Practices

1. Introduction

Cassava is an important staple food for millions of people living in the tropical world [1]. Cassava consumption is the highest per capita in the world and the crop provides expensive and reliable source of carbohydrates for people in Sub-Saharan Africa [2]. In Sierra Leone, the crop ranks as the second staple food after rice. The fresh storage roots of cassava contain largely starch and other nutrients including calcium (16 mg/100 g), phosphorus (27 mg/100 g), vitamin C (20.6 mg/100 g), and minute quantities of protein and other nutrients [3]. The leaves of the crop are consumed as vegetables since they possess protein such as lysine, but lack the amino acid methionine and possibly tryptophan. Moreover, the

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other cassava products utilized in the country are cassava pellets for animal feed, cassava starch for sweeteners, thickeners and textile paper industry [4].

Despite its importance, increased cassava productivity is fraught with lots of genetic, biotic and abiotic factors. According to Okere [5], grasshoppers, termites and green spider mites are the major pests of cassava. *Zonocerus variegatus* L. is the main grasshopper pest of crops including cassava, especially in the humid lowland forests and savannas of West and Central Africa. The hatching of eggs of grasshoppers is maximal at the start of the dry season spanning from late September-early November, with outbreak in November-April [6, 7]. The African variegated grasshopper species, *Zonocerus variegatus* L., is reported as the main pest of many crops in West and Central Africa including Sierra Leone, which occupies the extensive forest and savanna areas. The first report on damages of this grasshopper on crops were in 1910 by Peacock and Lamborns in Southern Nigeria [8], Schoutedem and Mayne in Zaire [9] and Small in Uganda [8]. Grasshopper impact on crops increased with time particularly under increased temperature. The current climate change has also been noted as a possible factor for the proliferation of the pests [9].

Zonocerus variegatus L. has been implicated in the transmission of okra mosaic viruses in Ivory Coast and cowpea mosaic viruses in Nigeria [9, 10] and causing huge yield loses. In 1948, it was reported that *Z. variegatus* accounted for 10% yield loss in the banana harvest in Guinea [8]. The pest is also known to cause 25 – 80% yield loss in garden eggs [8]. In Nigeria, it causes 50% loss in annual cassava fresh root yield [6]. In Sierra Leone, there is lack of information on smallholder farmers' perception on grasshopper pest on cassava in their farms. Moreover, there are no existing information on yield loses caused by grasshopper on cassava in the country. Such knowledge is important for the development of robust response strategies for the efficient monitoring and management of the pest.

This necessitates a study in this area since any successful crop improvement programme including efficient monitoring and management of the pest involves identification of constraints and preferences of end users. Producers mostly resist technologies that are incongruent with their expectation and preference [11]. Cassava cultivars that are selected for production, productivity, and market-orientation, should, therefore, meet most of the qualities if farmers and processors have to stay competitive in the market and increase income from cassava. The combination of desired traits that meet their culinary, agronomic and other needs are based on local knowledge which is translated into their everyday cultivar selection strategies and practices [12]. Participatory Rural Appraisal (PRA) is one of the needs assessment techniques usually utilized to solicit information on indigenous knowledge regarding a subject matter. The PRA technique permits the inclusion of various value chain actors in research decision making, planning the generation of new technologies, and serving as a non-formal approach for detailed data collection [13]. The incorporation of vital information obtained from the PRA in cassava breeding programmes would contribute to increased adoption of newly developed and improved cassava genotypes. Thus, the objective of this study was to evaluate the perception of smallholder cassava farmers on the severity of *Z. variegatus* L., its impacts on yield and indigenous coping management practices utilized to mitigate the infestation of grasshoppers in their cassava farms.

2. Material and methods

2.1. Description of Study Areas

Sierra Leone has similar agro-ecologies (humid forest zones) like most countries in the sub-Saharan Africa (SSA). In this research, selection of the research communities was based on the climatic and ecological conditions. Three Agro-Ecological, Cultural and Demographic Regions (AECD-Regions) viz; lowland savanna in the north, transition rain forest in the south and rain forest in the east, were selected for the current study. The selection of villages was done in consultation with key community stakeholders. The village communities covered in the east included; Blama, Waima and Serabu, in Small Bo Chiefdom, Eastern Sierra Leone. In the South, the communities included; New Mosongo, Old Mosongo, Mokonde and Bonganema, in the Kori Chiefdom, Moyamba District, Southern Sierra Leone. In the north, it included Gbassia, Rosente, Madina and Rokimbe, in the Patimasabong Chiefdom, Bombali District, Northern Sierra Leone. The investigation also took into cognizance the differences in climatic conditions in the agro-ecologies in the north representing the low land savanna, south representing the transition rain forest and the east representing the rain forest. These are very imminent environmental factors that influence the distribution of insect pests particularly the grasshopper (*Z. variegates* L.), that is dynamic in nature. Farmers in the three agro-ecologies employ different upland agricultural production systems. Most of smallholder cassava farmers in these communities practiced slash and burn agriculture. By tradition and culture, fallow periods vary considerably due to land demand for agriculture. Fallow period in the north is much shorter than the south and east. The farmers that plant cassava in these three agro-ecologies either use family labour or hired labour. Most often than not, they plant local varieties that are low yielding and also vulnerable to grasshopper attack. The crop is either planted solely or inter cropped. The adoption of the local varieties could probably be due to the less information disseminated about the improved varieties that would have served as a quick and sustainable remedy to grasshopper attack. There are two distinct seasons of equal durations in the three agro-ecologies in Sierra Leone. The dry season spans from November to April while the rainy season spans from May to October, respectively. If there are any alterations in the normal seasonal durations it could be attributed to climate change [14].

2.2. Research Design

A Qualitative research approach was used to obtain responses from respondents on severity, crop loss and management practices of variegated grasshopper (*Zonocerus variegatus* L.) on cassava (*Manihot esculenta* Crantz) in the study areas. The qualitative approach enabled the researcher to learn from the farmers' experiences. An approach within the qualitative to help investigate the research questions was the narrative approach. According to Frey [15], narrative approach is ideal if the researcher wants to describe the impact of a phenomenon such as a policy or practice on the lives of individuals by collecting and retelling their experiences. Also, this approach allowed for flexible and non-restrictive process in obtaining rich data as argued by Silverman [16] for qualitative study designs. The qualitative approach is best suited for researchers who want to find from respondents, their indebt understanding and opinion about a practice [16].

2.3. Sampling Techniques and Sample Size

In this study, not every member had equal chance of being selected and thus the use of non-probability technique [17]. The purposive and convenient sampling techniques were utilized to target those who are subjectively key individuals [18]. These sampled respondents provided relevant and rich data. These sources also provided insights into current and prior events on the topic. Moreover, the sampling techniques were also chosen so that selection of respondents was based on the researcher's judgment. This ensured that participants of the study have the required knowledge and relevant information [19].

According to Cochran [20], the population of a study is mostly large such that it is impractical or not feasible to use the whole population. Representative sample size selection becomes a crucial step. Therefore, researchers usually select some units or members of the population to be a representation of the entire population. This study used 300 respondents drawn from the key actors based on the guidelines by Cochran [20].

2.4. Data Collection Instruments

The questionnaire research instrument was utilized to gather data on demographics and views of cassava farmers on severity, crop loss and management practices of variegated grasshopper (*Zonocerus variegatus* L.) on cassava (*Manihot esculenta* Crantz) in Sierra Leone. Study period lasted from the 1st October, 2020 to 14th October, 2021, covering the research villages in the three agro-ecologies. Information gathering was based on Kobo collect.

The questionnaires were pre-tested in one of the nearby communities in Gbassia village, Pakimasabung Chiefdom, Bombali District, in 2020 to assess its validity before it was finally administered during the actual period of data collection in 2021. Key actors engaged in cassava production and productivity were interviewed separately. Gender responsiveness in agriculture was an integral dimension in the research. Sample size was 300, drawing 100 at random per province.

2.5. Statistical Analysis Technique

Data obtained in the study were first cleaned, coded and categorized according to the items in the questionnaires before data entry into Excel. The data was then imported into statistical package for social science (SPSS) and analyzed using descriptive statistics in SPSS (version 16.0). The results of the descriptive statistics were presented in tables. Regression analysis was done to explore the influence of grasshopper damage on cassava, grasshopper as major pest of cassava, farmers ability to recognize adult grasshoppers, best practices that contribute to increased cassava productivity, life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers and cassava variety preference by grasshoppers on extent of crop loss by grasshopper infestation [21].

3. Results and discussion

The results on the socioeconomic attributes of the respondents are presented in Table 1. The findings revealed that in the east, most (96%) of the respondents were males, while females were 4%. Similarly, in the north and south, the males exhibited higher percentages of 100% and 67%, compared to female values of 0% an 33%, respectively. In most livelihood activities including farming, gender differences often occur based on gender roles. The result is in agreement with the findings of Amadi *et al*. [22] who stated in their study on gender roles in cassava production in Imo state in

Nigeria, that men, women and youths were involved in the exercise but the number of men dominated the heavy labour operations. The findings revealed that across all the sampled provinces, most of the respondents involved in cassava farming are within the ages of 31-50 years, followed by those that were between 18 and 30 years old. These findings indicate that both higher numbers of youth and older people were involved in cassava farming. The results imply that agricultural knowledge could be transferred from the older generation to the younger generation. Similar findings have been reported by Chidiebere-Mark *et al*. [23], indicating the average age of rice farmers in different rice production system to be 49 years. Rahman [24] also opined that farmers in the age bracket of 40 years are energetic and have a lot of positive implications for crop production.

Table 1 Demographic attribute of respondent in the study area

Parameter	**Province**		
Gender	East	South	North
Male	96	67	100
Female	4	33	0
Age			
18-30yrs	30	25	40
31-50yrs	60	55	55
>50yrs	10	20	5
Educational level			
Primary	35	33	25
Secondary	10	19	14
No formal education	45	48	61
Yield loss equivalence to cash			
< Le 500,000	80	55	45
≥ 500,000	20	45	55

Most of (74) of the respondents exhibited no formal education in the east (45%), south (55%) and northern (61%) provinces (Table 1). This finding indicates high proportion of illiteracy amongst the smallholder cassava farmers. Bala *et al*. [25] also opined illiteracy as a key hindrance to institutional support towards agriculture, while Nyagaka *et al*. [26] revealed that education had positive relationship with agricultural efficiency and production. The annual household income of most of the respondents in the east (80%) and southern (55%) provinces is below Le 500,000 compared to the northern (55%) province where most receive at least Le 500,000. The findings on household income indicate that cassava farming is among the key sources, stabilizer and buffer of the household economic livelihood of smallholder cassava farmers. Thus, any exposure of the agriculture dependent smallholder vulnerable groups to risks, minor changes in climate and pollical instability can adversely affect household food security status and poses imbalances in their livelihoods.

Farmers' self-reported perceived ability to recognize adult grasshoppers was investigated and results recorded in Table 2. In the east, south and north, out of 100 farmers interviewed, all (100%) of the farmers confirmed they could self-identify adult grasshoppers on cassava plants. The issue that came out clearly is that adult grasshoppers are easily identified by cassava farmers due to their incidence and severity on their crops. This finding agrees with FAOSL and Njala University [14] who reported that farmers in general are good decision-makers and their views have contributed to the understanding of various aspects of the bio-ecology of insects and the real situation of other pests.

Table 2 Farmers perceived knowledge on grasshopper detection, cassava parts damaged and best practices to increase cassava productivity in Sierra Leone

Parameter	**Province**		
Farmers ability to recognize adult grasshoppers	East	South	North
Farmers can recognize adult grasshopper	100	100	100
Farmers cannot recognize adult grasshopper	0	0	0
Identification of part(s) of cassava plant mostly destroyed by grasshoppers			
Leaves	96	67	100
Stems	4	33	0
Both	0	0	0
Best practices that contribute to increased cassava productivity			
Early planting	80	85	10
Late planting	15	5	80
Planting of improved varieties	5	10	10

The result on the perception of the farmers' ability to identify the part(s) of cassava mostly affected by grasshopper is presented in Table 2. In the east, most (96%) of the farmers perceived the leaves as the mostly destroyed organ of the cassava plant, while only 4% of the farmers perceived the stems to be destroyed by the pest. In the north, all (100%) the respondents opined the leaves as the part of the plant severely affected by grasshoppers. In the south, 67% of the farmers perceived the leaves to be mostly destroyed by grasshoppers, while 33% of them perceived the stems to be destroyed by the pest. Findings indicate that the variegated grasshopper destroy both the leaves and the stems in smallholder farms of the studied agro-ecologies. Meanwhile, preferential feeding was observed by the farmers and reported which obviously starts from the leaves and ends on the stems. This could probably be as a result of 'choice, no choice' or preferential feeding patterns in the pests. This is in line with Gurung [27] who stated that the pest is dynamic in nature and voracious and feeds both on the leaves and stems using the leaves as the first preference in its feeding.

Farmers' perception on existing best practices are presented in Table 2. In the eastern province, most (80%) of the respondents, perceived early planting as best practice that contributes to increased cassava productivity, while 15% of the respondents perceived late planting as the best practice, and 5% opined planting of improved varieties as the best practice to resolve the biological constraint. Similarly, in the south, 85% of the respondents perceived early planting as best practice in cassava production, while 5% perceived late planting and 10% perceived planting of improved varieties as best practice. In the north, 80% of the farmers opined late planting as the best practice, while equal scores of 10% each perceived early planting and planting of improved varieties, as the best practices in grasshopper management. In crop production systems in Sierra Leone like elsewhere in the Sub-Saharan Africa (SSA), farmers use best practices an IPM option as pest management strategy. These perceived abilities regarding the identification of existing best practices in grasshopper management on cassava by the framers in the study areas is in agreement with Gurung [27] who opined that many cassava pests are dry season pests. The grasshopper pest l causes greater yield loss in cassava planted at the end of the wet season (late planting) than at the beginning of the wet season (early planting).

All the cassava farmers in the studied agro-ecologies opined their perceived abilities to identify grasshopper damage in their cassava farms (Table 3). Grasshoppers are the major insect pests of cassava in Sierra Leone like in most tropical countries where the crop is grown. They are distributed in almost every part of Sierra Leone, making farmers to be familiar with their damage, severity pattern and identification. These findings are in concurrence with the survey outcomes conducted by the UNDP ecologically Sustainable Cassava Plant Protection project [28]. The overall objective of the project was to identify and prioritize cassava pests both from farmers' perspective and through scoring in the field.

The farmers in the three agro-ecologies were interviewed on their perceived abilities to confirm grasshoppers as the main pest of cassava (Table 3). Findings revealed that all (100%) of the respondents opined grasshopper as the main pest of cassava. Several studies conducted within Sierra Leone and outside on farmers' perceived knowledge on grasshoppers as main pest on cassava have justified this claim [6, 29, 30]. This finding is in line with Barker *et al.* [31], who reported that in southern Nigeria over 50% of the cassava crop is estimated to be lost in years of high *Z. variegatus* abundance. This report is also in support of findings by Bernays and Chapman [32], who stated that in Sierra Leone, grasshopper is one of the insect pests that attack and causes considerable yield loss in cassava growing provinces.

Farmers' self-perceived abilities to identify the stage(s) in the life cycle of the grasshopper that cause severe cassava damage was assessed and recorded in Table 3. In the east, 90% of respondents perceived the adults as the most destructive stage on cassava plants, while 6% of the respondents perceived the nymphs as destructive stage and 4% perceived the eggs as destructive. In the South, 85% of smallholder farmers perceived the adults as the most destructive stage, followed by the nymphs (10%) and the least was accounted for by the eggs (5%). In the north, 90% farmers perceived the adults as the most destructive stage on cassava, while equal scores of 5% each of the respondents perceived the eggs and nymphs as the destructive stages. The perception differences among the respondents across the three agro-ecologies show divergence in the knowledge depth and practices of the traditional farmers regarding their opinions on the identification of the destructive stages in the life cycle of the grasshoppers. Similar research was conducted in Cameroon but there was no indication of grasshopper eggs feeding directly on cassava nor the nymphs hardly feed on cassava plants that is less than 7 months old. The inability of the nymphs to feed is simply due to the high hydrogen cyanide concentration in the plant at that age. Grasshopper adults feeding on cassava is in agreement with the findings of Bernays and Chapman [32], who opined that grasshopper nymphs do not feed on cassava leaves due to the high hydrogen cyanide concentration, while the adults fecundate on the crop.

Table 3 Farmers' perception on cassava variety preference, grasshopper damage, life cycle stage(s), and extent of crop loss of cassava at agro-ecological levels in Sierra Leone

Parameter	**Province**		
Cassava variety preference by grasshoppers	East	South	North
Improved	2	0	10
Local	98	100	90
Grasshopper damage on cassava			
Farmers can recognize grasshopper damage	100	100	100
Farmers cannot recognize grasshopper damage	0	0	0
Grasshoppers as major pest of cassava			
Farmers recognize grasshopper as a major pest	100	100	100
Farmers do not recognize grasshopper as a major pest	0	0	0
Life cycle stage(s) of the grasshoppers			
Eggs	4	5	25
Nymphs	6	10	25
Adults	90	85	50
Extent of crop loss by grasshopper infestation			
Very severe	90	51	39
Severe	8	2	36
Less severe	2	47	25

Result on farmers' perceived ability on crop loss assessment across the three ago-ecologies among the cassava farmers interviewed was recorded in Table 3. In the east, most (90%) of the smallholder farmers opined that fecundation of grasshopper on cassava caused very severe damage on cassava plants, while 8% of them perceived it to be optimal and 2% perceived it to be less severe. Similarly, in the south, 51% of respondents perceived grasshopper feeding to being very severe, 47% perceived it to being less severe, while only 2% perceived it to being optimal. In the north, 39% of respondents perceived grasshopper feeding causes very severe damage to cassava, while 36% perceived it to being optimal and the least was recorded by 25% of the farmers who opined that their attack cause less severe damage to the crop. Results indicate that fecundation of grasshopper cause severe damage to cassava and that the degree of damage caused by pest varies across agro-ecologies These findings are in agreement with the view of Okere [5] who stated that grasshopper is a voracious and destructive insect on cassava whose cumulative feeding leads to severe reduction of crop yield.

Table 4 shows the summary of the fitted or estimated linear regression model by the method of least square. The extent of crop loss by grasshopper infestation is used as dependent variable and best practices that contribute to increased cassava productivity, life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers, and cassava variety preference by grasshoppers as independent variables. The coefficients of determination (R^2) values indicate that 52.3% of variation in extent of crop loss by grasshopper infestation was due to the best practices that contribute to increased cassava productivity, life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers, and cassava variety preference by grasshoppers (Table 4).

Table 4 Regression analysis of variance (ANOVA) and statistics for independent and dependent variables of respondents across selected cassava agro-ecologies of Sierra Leone

ANOVA						**Regression statistics**			
Model	**Df**	**Sum of Squares**	**Mean Square**	**F**	**Sig.**	**R**	**R^2**	**Adjusted R^2**	**SE**
Regression	4	113.300	28.325	80.931	0.000	0.723	0.523	0.517	0.592
Residual	295	103.247	0.350						
Total	299	216.547							

Independent variables=(constants: GDC=grasshopper damage on cassava, GMPC=grasshopper as major pest of cassava, FARAG=farmers ability to recognize adult grasshoppers); BPCICP=best practices that contribute to increased cassava productivity; LCSG=life cycle stage(s) of the grasshoppers, IPCPMDG=identification of part(s) of cassava plant mostly destroyed by grasshoppers; CVPG=cassava variety preference by grasshoppers; dependent variable=extent of crop loss by grasshopper infestation; Df=degree of freedom; R^2=coefficient of determination; SE=standard error

The coefficients of life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers and best practices that contribute to increased cassava productivity show that extent of crop loss by grasshopper infestation will increase by 0.382, 1.111 and 0.515 units, respectively, holding other factors as constant (Table 5). These coefficients are significant ($p<0.05$) at 5% level of significance. Findings generally indicate that the identification of grasshopper damage symptoms, stage(s) in the life cycle of the pest that is/are more destructive regarding crop losses and utilization of best practices to mitigate grasshopper infestation on cassava affects extent of crop loss by grasshopper infestation to varying degrees.

Table 5 Regression statistics for independent and dependent variables

	Coefficients	**Standard error**	**t statistics**	**P-value**	**95% CI of the difference**		**Collinearity Statistics**	
					Lower	**Upper**	**Tolerance**	**VIF**
Intercept	-0.620	0.36	-1.722	0.086	1.197	1.507		
CVPG	-0.388	0.20	-1.898	0.059	0.007	0.193	0.73	1.38
LCSG	0.382	0.06	6.391	0.000	0.002	0.156	0.71	1.40
IPCPMD	1.111	0.11	10.163	0.000	-0.063	0.078	0.90	1.11
BPCICP	0.515	0.06	9.285	0.000	-0.087	0.056	0.91	1.10

Dependent variable=extent of crop loss by grasshopper infestation; independent variables CVPG=cassava variety preference by grasshoppers; LCSG=life cycle stage(s) of the grasshoppers; IPCPMD=identification of part(s) of cassava plant mostly destroyed by grasshoppers; BPCICP=best practices that contribute to increased cassava productivity; CI=confidence interval; VIF=variance inflation factor. Source: Field survey 2020

4. Conclusion

The farmers perceived *Z. variegatus* as a serious socio-economic pest of cassava cultivated in the low land savanna, transition rain forest and rain forest agro-ecologies of Sierra Leone. The study established that smallholder farmers have perceived abilities to identify damage symptoms, stage(s) in the life cycle of the pest that is/are more destructive leading to crop losses and utilization of best practices to mitigate grasshopper infestation on cassava that could be exploited for increased production, management and conservation of cassava genetic resources. Findings also established that 52.3% of variation in extent of crop loss by grasshopper infestation is attributable to life cycle stage(s) of the grasshoppers, identification of part(s) of cassava plant mostly destroyed by grasshoppers, cassava variety preference by grasshoppers and the best practices that contribute to increased cassava productivity.

Compliance with ethical standards

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Disclosure of conflict of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

Statement of ethical approval

The study was reviewed by the Research and Ethics Committee of Njala University, and after the ethics clearance, permission was sought from the Ministry of Agriculture and Forestry District Offices before undertaking the research, ethical approval was sought from various sources to ensure that the study adheres to acceptable ethical guidelines.

Statement of informed consent

In addition, Informed consent was obtained from each study participant. Each respondent was informed about the purpose of the study that the findings of the study will inform policy makers.

Authors' contributions

TSJ, FSN: Conceptualization of the work, experimental design and revision of the manuscript. TSJ, AES, AJS, DDQ, FSN, KSA, MDP, PEN: Discussion of results, support and supervision of the study. TSJ, AES, AJS, DDQ, FSN, KSA, MDP, PEN: Fieldwork supervision, manuscript review. TSJ, AES, MDP, FSN: Support and supervision in field work, manuscript revision. TSJ, AJS, FSN, KSA, MDP, PEN: Experimental design, statistical analysis of results. TSJ, AJS, PEN: Field work carried out, review of statistical analysis of results. TSJ, FSN, AES: Logistics management, execution of field work.

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