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Full Length Research Paper

Woody species composition and structure of Amoro Forest in West Gojjam Zone, North Western Ethiopia

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Ethiopia is one of the biodiversity reach areas in the world. A study was conducted at Amoro Forest to determine the woody species composition, vegetation and population structure. Vegetation data were collected from 36 plots (900 m^2) systematically laid along transects. A hierarchical cluster analysis with R software was used to identify plant communities. Structural analysis of the forest was performed based on frequency, density, DBH, basal area and importance value indices (IVI) of woody species. A total of 57 woody species belonging to 38 families were encountered, consisting of 19 tree (33.33%), 31 (54.38%) shrubs, and 7(4.37%) liana species. The vegetation of the forest was classified into four plant communities namely, *Calpurnia aurea-Vernonia myriantha, Vernonia myriantha-Euphorbia abyssinica, Laggera tomentosa-Solanecio gigas, Allophyllus abyssinicus-Bersama abyssinica* based on cluster analysis. The total basal area and density of woody plants were 18.5 m^2/h and 2860.49 stems/h respectively. The DBH distribution showed a reverse "J" shaped curve, meaning that there is active regeneration and recruitment in the forest. Four representative woody plant population structures were identified, that is, inverted J, Gauss I, Gauss II and J- shaped patterns. There is high anthropogenic effect and high dependence of the local community in Amoro Forest so that forest conservation and restoration measures should be required.

Key words: Ethiopia, Amoro Forest, vegetation communities, anthropogenic activities and population structure.

INTRODUCTION

Ethiopia is an important regional biological diversity hotspot due to wide ranges of altitude, and geographical features, such as high and rugged mountains, flat-topped plateaus, deep gorges, river valleys and rolling plains (Kelbessa et al., 1992; Woldu, 1999). These contributed to emergence of a variety of habitats suitable for the evolution and survival of various plant and animal species.

The rich biodiversity resources, including forests, are being destroyed at an alarming rate largely due to human

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related disturbances (Aynekulu, 2011). North western highlands of Ethiopia have only fragments of natural forests scattered and confined to inaccessible and sacred places (Wassie et al., 2005), which suggested that the highlands were once covered by high forests. Therefore, appropriate and immediate measures are required to maintain and restore the remaining natural forests. Accelerated deforestation that arise largely due to the conversion of forests to other agricultural land-use types and the overutilization of forest resources to satisfy the food and energy requirements of the increasing population are major environmental concerns in Ethiopia (Friis et al., 2001; Teketay, 2001). In the absence of suitable interventions, current patterns of deforestation will decimate the remaining forests in the near future (Teketay, 1992; Bekele, 1993, 1994).

Amoro Forest is composed of patches of dry evergreen Afromontane forests found in north western part of Ethiopia. It has been continuously exploited by surrounding communities for agricultural land, firewood collection and charcoal production and construction material. *Prunes africana* is highly sought by locals for fuel wood and charcoal production (Personal observation). Detailed description of resource exploitation needed analysis of floristic composition and structural complexity could contribute towards the conservation of vegetation resources. It is additionally important to document the remaining vegetation resources for posterity. Nevertheless, such data on woody plant composition, community and structural complexity are lacking for the Amoro forest in Dega Damot District and hence the current study. This is believed to contribute a lot to the effort being made in the development of a sound management plan for effective conservation of the forest resources in the study area.

MATERIALS AND METHODS

Study area

Amoro Forest is located in Dega Damot District, Amhara Regional State, North western Ethiopia (Figure 1). The forest is located between 10°50'06.53" latitude 37°35'51.94" longitude. The major town nearby is Feresbet and is far from 3 km from the forest. The district is also characterized by good climate for most of the year with annual rainfall between 900 and 1200 ml. Topographically, it consists of 35% mountainous, 30% ups and downs, 20% valleys and 15% plains. The soil of the district is reddish (clay soil), black soil, sand soil, brown soil and white soil types (Dega Damot Woreda Agricultural Office (DWAO), 2017).

The area is divided into six land use types such as farm land, grazing land, shrub land, settlement, forest and bare land. Different types of crops cultivate in the study area crops including barley (*Hordeum vulgare*), wheat (*Triticum* spp.), faba bean (*Vicia faba*), teff (*Eragrostis tef*), maize (*Zea mays*) and potato (*Solanum tuberosum)* (DWAO, 2017).

Amoro Forest belongs in the category of dry evergreen Afromontane vegetation (Friis et al., 2011). The vegetation of the forest is dominated by trees; *Juniperus procera*, *Olea europaea* subsp*. cuspidata, Allophylus abyssincus, Apodytes dimidiata*, *Bersama abyssinica.* Shrub and short stature trees such as; *Carissa spinarum*, *Discopodium penninervium, Dombeya torrida*, *Lobelia giberroa*, *Myrsine africana* and *Pittosporum viridiflorum.* The most dominant liana is *Urera hypselodendron.*

Sampling design

Reconnaissance survey was made across the forest in order to get an impression of the site conditions and identify the possible sampling sites. Systematic sampling technique was used for vegetation data. Sampling sites were arranged along transects in two directions (NW and SW) from the top to the base of the forest. The number of plots per transect varies depending on length of the transect and accessibility of the sample plots. A total of 36 sampling plots of each 30 m x 30 m (900 m^2) was used for woody species. The distance between two consecutive plots along a line transect was 50 m and the transects were 100 m apart.

Vegetation data collection

Diameter at breast height of each tree and shrub species with a diameter of ≥ 2.5 cm was measured using tree calipers. The number of individuals of each woody species was counted for each plot. Geographical data (altitude, latitude and longitude) were recorded using GPS for each plot. The percentage cover values estimated in each sample plot were converted into cover abundance values using 1-9 modified Braun-Blanquet Scale (Van der Maarel, 1979). Voucher specimens were collected, coded, pressed and dried for subsequent identification and verification at the National Herbarium (ETH), Addis Ababa University, using Volume 8 of Flora of Ethiopia and Eritrea (Hedberg et al., 2009b).

Data analysis

Cluster analysis

Hierarchical cluster analysis was performed using R-free statistical software version 3.4.1 to identify plant communities (R Core Team, 2017). Cluster analysis helps to group together a set of observations (plots or vegetation samples in this study) based on their attributes or floristic similarities (Kent and Coker, 1992). The community types identified from the cluster analysis were further refined in a synoptic table, and species occurrences are summarized as synoptic-cover abundance values. Synoptic values are the product of the species' frequency and average cover abundance value (Bekele, 1993). Dominant species of each community type were identified based on their synoptic values. Finally, the community types were named based on two dominant species. Shannon-Wiener diversity indices and Shannon's evenness were computed to describe species diversity of the plant community types in the vegetation (Kent and Coker, 1992).

$$H' = -\sum_{i=1}^{s} Pi \ln pi \quad (1)$$

where
H' = Shannon diversity index
s = number of species,
p= proportion of individuals or abundance of the ith species expressed as a proportion of total cover in the sample; and *ln* = the natural logarithm.

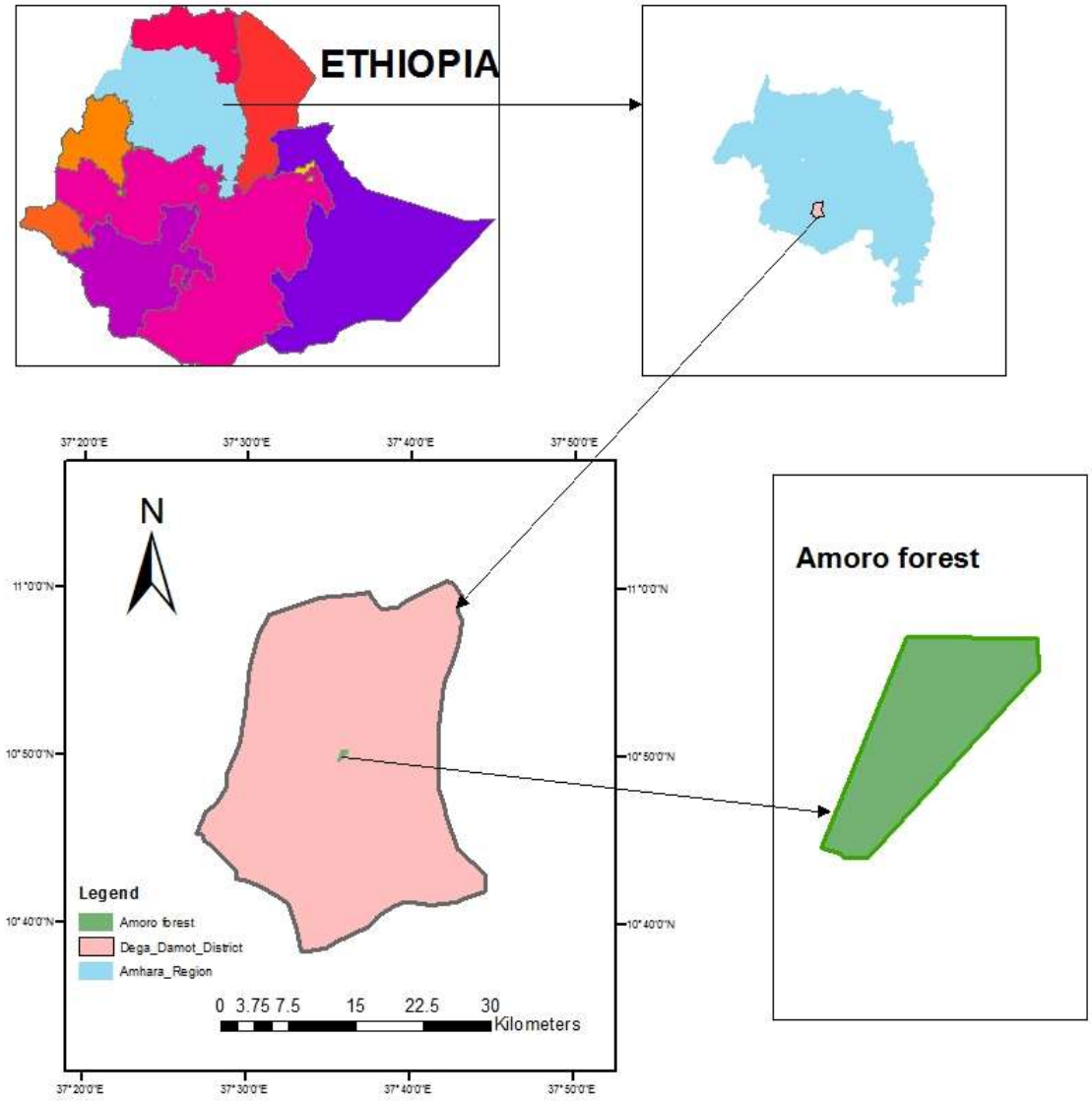

Figure 1. Map of the study area.

Shannon's evenness index (J) was also calculated using:

$$J = {}^{H'}/_{H'max} \quad (2)$$

where, H' = Shannon–Wiener Diversity Index; and H'max = lns where s is the number of species in the sample.

Structural data analysis

Structural characteristics (stem density, basal area, and DBH class distributions) were calculated for each woody plant species. Generally, the following formulas were used to calculate frequency, density and basal area of woody species.

$$Frequency\ (F) = \frac{Number\ of\ plots\ in\ which\ a\ species\ occurs}{Total\ number\ of\ plots} \times 100 \quad (3)$$

$$Density = \frac{Total\ number\ of\ stems\ of\ all\ trees}{Sample\ size\ in\ hectare} \quad (4)$$

$$BA = \left(\frac{DBH}{2}\right)^2 \times \pi \text{ with } (\pi = 3.14) \quad (5)$$

where DBH is diameter at breast height.

Importance value indices (IVI) were computed for all woody species based on their relative density (RD), relative dominance (RDO) and relative frequency (RF). This index is used to determine

Table 1. Synoptic table of the four community types (values in bold refer to species used to name community types).

Species	C1	C2	C3	C4
Calpurnia aurea	**7.78**	**3.7**	3	0.7
Vernonia myriantha	**6.22**	**6.7**	4.2	4.5
Euphorbia abyssinica	2.89	**5.7**	4	2.5
Clausena anisata	4.8	4.6	1.25	0
Laggera tomentosa	3.1	0	**6.5**	0
Solanecio gigas	1.5	2.4	**6.2**	5.7
Urera hypselodendron	1.7	2.7	6.0	2.7
Lobelia giberroa	0	1.9	6.0	1.7
Vernonia amygdalina	0.4	0.3	4.2	0
Allophyllus abyssinicus	1.3	4.7	6.2	**7.0**
Bersama abyssinica	5.3	1.1	2	**6.5**
Brucea antidyssentrica	5.1	2	2	3.2
Discopodium penninervium	3.4	3.5	3.2	3.0

the overall importance of each species in the forest system (Kent and Coker, 1992).

The Importance Value Index (IVI) for each woody species was computed using the following formula:

$$RDO = \frac{BA}{TBA} \times 100 \quad (6)$$

where
RDO= relative dominance
BA= Basal area
TBA= total basal area

$$Relative\ Density = \frac{Number\ individuals\ of\ each\ species\ per\ ha}{Total\ number\ of\ individuals\ of\ all\ species\ per\ ha} \times 100 \quad (7)$$

$$Relative\ Frequency = \frac{Number\ of\ sample\ plots\ containing\ a\ species}{Sample\ units\ for\ all\ species\ of\ the\ sample} \times 100 \quad (8)$$

$$IVI = Relative\ Density + Relative\ Dominance + Relative\ Frequency, \quad (9)$$

Population structure of woody species was analyzed for the entire forest and each woody species based on defined DBH classes. Diameter was classified into seven classes. DBH classes (cm) were 2.5–10, 10.1–20, 20.1- 40, 40.1-60, 60.1-80, 80.1-100, > 100 cm).

RESULTS AND DISCUSSION

Forest composition

A total of 57 woody species representing 38 families were recorded from 36 plots (Appendix Table 1). Of the total plant species identified, 19 species (33.33%) are trees while 31 species (54.38%) are shrubs. The remaining 7 species (4.37%) are lianas.

The results of this study show that the woody species composition of Amoro Forest (57 species) were higher than many Afromontane forests in Ethiopia and other tropical forest. For instance, Tadele et al. (2014) recorded a much lower species (50 species) in Zengena Forest in Ethiopia, Berhanu et al. (2016) recorded 66 woody species in Kuandisha Afromontane Forest in Ethiopia; whereas Neelo et al. (2015) recorded 47 woody species in open and exclosed dry woodland sites around *Molapo* farming areas of the Okavango Delta in Botswana. On the other hand, Zegeye et al. (2011) recorded a much higher woody species 143 species in Tara Gedam and Abebaye forests in Ethiopia. The reasons for variation in floristic composition at the study sites could be due to excessive anthropogenic disturbances, disparity in conditions for regeneration and exploitation of some species. Besides this, the geographical location of the study area differs from other areas. According to Chen et al. (2004), environmental heterogeneity, regeneration success and competition are also important factors that shape species composition of forests.

Four plant community types were identified from the hierarchical cluster analysis, *Calpurnia aurea-Vernonia myriantha, Vernonia myriantha-Euphorbia abyssinica, Laggera tomentosa-Solanecio gigas, Allophyllus abyssinicus-Bersama abyssinica* (Figure 2; Table 1). Unfortunately, this study did not address analyses of a range of possible environmental variables except altitude that could shape the distribution of identified plant communities. The cluster results of four groups of communities in the present study suggest the existence of overlapping altitudes (Körner, 2000).

***Calpurnia aurea-Vernonia myriantha* type:** This occurs between altitudinal 2432 and 2615 m a.s.l. This community

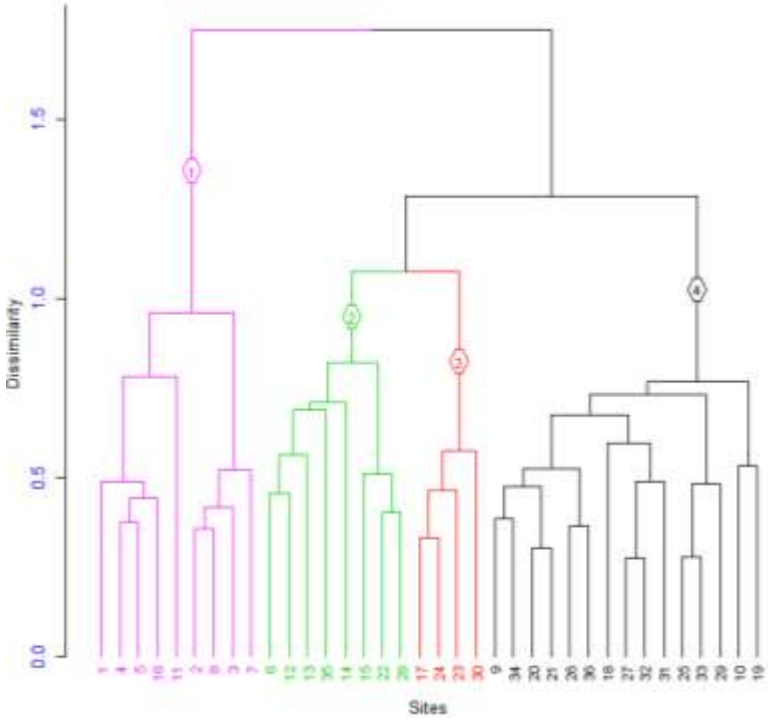

Figure 2. Dendrogram of the vegetation community types obtained from hierarchical cluster analysis of Amoro forest. (1= Community type 1, 2= Community type 2, 3= Community type 3 and 4= Community type 4).

type is characterized by *C. aurea* and *V. myriantha* as the dominant shrubs. Other important species in this group include *Clausena anisata, Clutia abyssinica, B. abyssinica, C. anisata, Euphorbia abyssinica, Maytenus arbutifolia and Dovyalis abyssinica.*

***Vernonia myriantha-Euphorbia abyssinica* type:** This community type was situated at altitudinal of 2455 to 2622 m a.s.l. This community was dominated by *V. myriantha* and *E. abyssinica.* Some of the species are *C. anisata, C. aurea, A. abyssinicus, D. penninervium and U. hypselodendron.*

***Allophyllus abyssinicus-Bersama abyssinica* type:** This was encountered at an altitudinal range of 2463–2728 m a.s.l. This community type was dominated by *A. abyssinicus and B. abyssinica.* The tree layer consists of tree species such as *P. africana, A. dimidiata and E. abyssinica.* The shrub layer includes *C. aurea, L. giberroa, M. arbutifolia, D. penninervium* and *Liana* species are *Rubus steudneri* and *Embelia schimperi.*

***Laggera tomentosa-Solanecio gigas* type:** This community type extends from 2493 to 2567 m a.s.l. In this community type, *L. tomentosa and S. gigas* are the dominant shrub.

Shannon`s diversity indices showed that use of the name as described above had the highest species diversity (3.62) followed by Communities 2 and 3 (Table 2). On the other hand, Community 1 had the highest number of species (47) and Communities 3 and 4 the lowest (29). Community 1 followed by communities had the highest evenness value. While Communities 2 and 3 had the least evenness value (Table 2).

Vegetation structure

The density of trees and shrubs with DBH greater than 2.5 cm in the Amoro Forest was 2860.5 stems ha^{-1} (Appendix Table 2). The forest had relatively high density compared with that of Zengena Forest in North western Ethiopia (Tadele et al., 2014). On the other hand, the density was low compared to some other dry Afromontane Forest in Northwestern Ethiopia such as Tara Gedam and Abebaye Forests (Zegeye et al*.,* 2011), Kuandisha Afromontane Forest (Berhanu et al*.,* 2016) and peninsula of Zegie (Alelign et al*., 2007*). The density of the woody species varied considerably in the different forests. This could be attributed to variations in topographic gradients and habitat preferences of species forming the forest, and the degree of anthropogenic

Table 2. Species diversity, richness and evenness of the plant community.

S/N	Type of community	Species richness	Diversity index(H)	Shannon_Evenness (J)
1	*Calpurni aurea-Vernonia myriantha*	47	3.62	0.94
2	*Vernonia myriantha-Euphorbia abyssinica*	44	3.40	0.898
3	*Laggera tomentosa- Solanecio gigas*	29	3.00	0.892
4	*Vernonia myriantha-Allophyllus abyssinicus*	29	3.14	0.93

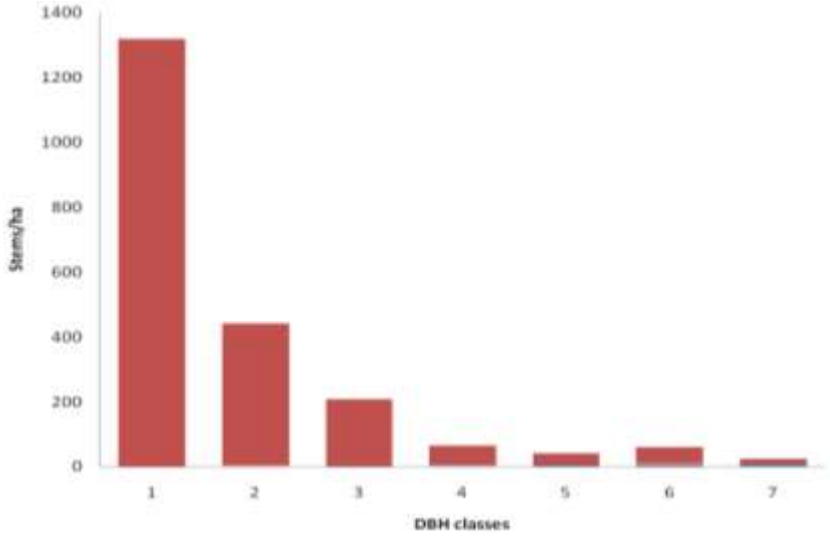

Figure 3. Distribution of woody species density among DBH classes (1=2.5-10 cm, 2=10.1-20 cm, 3=20.1-40 cm, 4=40.1-60 cm, 5=60.1-80 cm,6=80.100 cm,7= >100 cm.

disturbances (Whittaker et al., 2003). The density of the desired species reduced due to the devastating effects and lack of afforestation.

The species with the highest frequency value was *V. myriantha* (94.4%) followed by *A. abyssinicus* (88.9%), *P. africana (83.3%), Brucea antidyssentrica* and *D. penninervium (*75% each*)* and *E. abyssinica (*72.2%) (Appendix Table 2). High frequency value represents a wider distribution of the species in the forest. The variation in density and frequency among species may be attributed to differences in site conditions, species characteristics for adaptation, degree of exploitation and conditions for regeneration (Shibru and Balcha, 2004).

The total basal area of woody species in Amoro Forest was 18.5 m^2 ha^{-1} and comparable to other Afromontane Forests in Ethiopia like Kuandisha Afromontane Forest (Berhanu et al*.,* 2016) and Zengena Forest (Tadele et al., 2014). However, the basal area of this forest is small compared to other dry Afromontane Forests in Ethiopia like Tara Gedam and Abebaye Forests (Zegeye et al*.,* 2011), Wof-Washa Forest (Bekele, 1993) Adelle and Boditi Forests (Yineger et al., 2008). The normal basal area value for virgin tropical forests in Africa is 23-37 m^2/ha (Lamprecht, 1989). Thus, the basal area of Amoro Forest is low compared to tropical forests in Africa including dry Afromontane Forests found in Ethiopia. This may be due to Amoro Forest being dominated by shrubs. Besides this, cutting down trees and other factors influenced species by reducing the number of stems desired, affected species diversity and their size.

The distribution of woody species showed in decrease from lower to higher among DBH classes (Figure 3). The forest showed a reverse "J" distribution. These results were similar for those of Savadogo et al. (2007) in Tiogo Forest. The density was most abundant at DBH classes less than 10 cm (1318 stems ha^{-1}), 10 -20 cm (440 stems ha^{-1}), 20-40 cm (205.556 stems ha^{-1}), 40-60 cm (60.802 stems ha^{-1}),60-80 cm (28.086 stems ha^{-1}) and >100 cm (17.901 stems ha^{-1}). This pattern indicates that the majority of the species had the highest number of individuals in lower DBH which in turn shows that the forest vegetation has good reproduction and recruitment potential.

Schefflera abyssinica had the highest IVI (41.0) followed

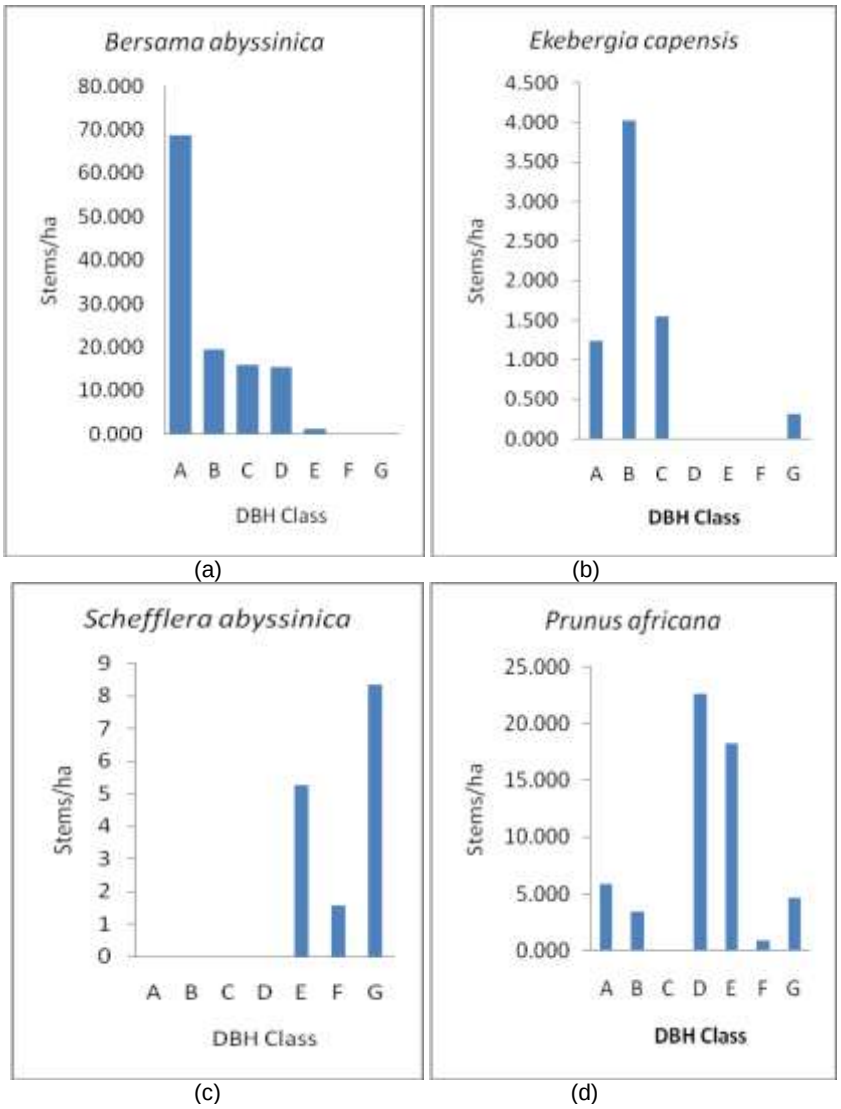

Figure 4. Size structure composition of a)**,** *Bersama abyssinica* , b) *Ekebergia capensis* , c) *Schefflera abyssinica*, d), *Prunus africana* tree and shrub species from Amoro forest, Ethiopia. (A=2.5-10 cm, B=10.1-20 cm, C=20.1-40 cm, D=40.1-60 cm, E=60.1-80 cm,F=80.1-100 cm,G=> 100 cm).

by *P. africana* (30.7), *A. abyssinicus (*25.4*), A. dimidiata (*23.3*), V. myriantha* (17.8), *S. gigas (*12.3), *C. aurea* (10.7), *E. abyssinica (*10.6), *B. abyssinica (*9.4) (Appendix Table 2). IVI value is an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht, 1989).

Population structure

The woody tree and shrub species in Amoro Forest were analyzed in four representative size structure (Figure 4a-d). The first pattern was an inverted J-shaped distribution exhibited by species with high number of individuals in the first and second DBH classes and with gradual decrease of larger sized trees (Figure 4a). This pattern was recorded on *B. abyssinica,* suggesting adequate seedling reproduction and regeneration (Bekele, 1993). Gause II (Figure 4b) lacked individuals at intermediate DBH classes and indicates the sizes missing and individuals present at the high and lower DBH classes. The species *Ekebergia capensis* shows this type of pattern. This kind of distribution is observed when there is selective logging of medium sized individual. In my observation, the main reasons for the absence of medium DBH classes were selective cutting for construction,

charcoal production timber and firewood.

The J shaped was characterized by a higher proportion of larger individuals with over 40 cm DBH (15.12 stem/ha). The trend decreased towards lower DBH classes and absence of smaller individuals below 40 cm DBH (0 stem/ha). This regeneration pattern was observed in *S. abyssinica.* Such pattern shows poor reproduction (Bekele, 1993) due to the fact that it is possible most trees are not producing seeds due to age. It also indicates the presence of selective cutting of preferred size classes on juvenile individuals by local. The species with this type of pattern have large individuals that are less competent to reproduce and in a weak position of regeneration status selective cutting or grazing effects on juvenile individuals.

Gause I was represented by *P. africana* (Figure 4d). The first and second DBH classes having low number of individuals, a gradual increase in the number of individuals towards the medium classes, and subsequently a decrease in number towards the higher DBH classes. This pattern indicates a poor reproduction (Bekele, 1993) and recruitment of species which may be associated with human use selectively harvesting branches of stem for construction material and charcoal production.

CONCLUSION AND RECOMMENDATION

The woody plant of Amoro Forest are dominated by shrubs (54.38%). Euphorbaceae was the dominant family with six species (10.52%) followed by Asteraceae family with four species (7.01%). Amoro Forest is mainly a dry evergreen Afromontane Forest which is dominated by small sized tree and shrub species. The general size composition of trees in the forest was inverted J, however there were differences among tree species. *B. abyssinica* species showed typical healthy inverted, whereas *S. abyssinica* species J with predominance of adult and absence of juveniles. *P. africana* and *Ekebergia capensis* showed Gausian form with absence of intermediately sized individuals attributed to selective harvest. The density of woody species decreases with increasing DBH indicating predominance of small sized individuals in the forest. This implies that the forest is in good state of reproduction.

Therefore, to improve the natural diversity and structure of the forest, to minimize the influence of the surrounding communities and utilize the forest resources sustainably for present and future generation, it is necessary to take measures for protection of the forest human interference and other anthropogenic influences.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Appendix Table 1. List of woody plants recorded at Amoro Forest.

S/N	Scientific name	Family	Vernacular name/Amharic	Habit
1	*Acalypha psilostachya Hochst.*	Euphorbiaceae	Nacha	Shrub
2	*Acanthus sennii* Chiov.	Acanthaceae	Kosheshila	Shrub
3	*Albiziasc himperiana* Oliv.	Fabaceae	Sesa	Tree
4	*Allophylus abyssinicus* (Hochst.) Radlk.	Sapindaceae	Abalat	Tree
5	*Apodytes dimidiata* E.Mey.ex Arn	Icacinaceae	Dong	Tree
6	*Arundinaria alpina* K. Schum.	Poaceae	Kerkeha	Shrub
7	*Asparagus africanus* Lam.	Asparagaceae	Yeset Kesit	Liana
8	*Bersama abyssinica* Fresen.	Melianthaceae	Azamira	Shrub
9	*Bridelia micrantha*	Euphorbiaceae	Yenebir Tifir	Shrub
10	*Brucea antidysenterica*	Simaroubaceae	Abalo	Shrub
11	*Buddleja polystachya* Fresen.	Loganiaceae	Nech Anifar	Shrub
12	*Buddleja davidii* Franch	Loganiaceae	Tikuir Anfar	Shrub
13	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Ligita	Shrub
14	*Carissa spinarum* L.	Apocynaceae	Agam	Shrub
15	*Clausena anisata* (Willd.) Benth.	Rutaceae	Limich	Shrub
16	*Clematis longicauda* Steud. exA.Rich.	Ranunculaceae	Azo harg	Liana
17	*Clutia abyssinica* Jaub. & Spach	Euphorbiaceae	Fiyelefej	Shrub
18	*Croton macrostachyus* Del.	Euphorbiaceae	Bisana	Tree
19	*Discopodium penninervium* Hochst	Solanaceae	Aluma	Shrub
20	*Dodonaea anguistifolia* L.f	Sapindaceae	Kitkita	Shrub
21	*Dombeya torrida* (J.F.Gmel) P. Bamps	Sterculiaceae	Wulkifa	Tree
22	*Dovyalis abyssinica* (A. Rich) Warb	Flacourtiaceae	Koshim	Shrub
23	*Ekebergia capensis* Spamn.	Meliaceae	Lol	Tree
24	*Embelia schimperi* Vatke	Myrsinaceae	Enkoko	Liana
25	*Erythrina brucei* Schweinf.	Fabaceae	Korch	Tree
26	*Euphorbia abyssinica* Gmel.	Euphorbiaceae	Kulkual	Tree
27	*Ficus sur* Forssk.	Moraceae	Shola	Tree
28	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	Yeabesha Tsid	Tree
29	*Laggera tomentosa* Sch.Bip	Asteraceae	Gimane	Shrub
30	*Lippia adoensis* Hochst.ex Walp.	Verbenaceae	Kesy	Shrub
31	*Lobelia giberroa* Hemsl.	Lobeliaceae	Gibera	Shrub
32	*Maesa lanceolata* Forssk	Myrsinaceae	kilaba	Shrub
33	*Maytenus arbutifolia* (A.Rich.) Wilczek	Celastraceae	Atat	Shrub
34	*Maytenus obscura* (A.Rich.) Cuf.	Celastraceae	Qoba	Tree
35	*Myrica salicifolia* A.Rich	Myricaceae	Shihnet	Tree
36	*Myrsine africana* L.	Myrsinaceae	Kechemo	Shrub
37	*Olea capensis* L. subsp. *macrocarpa* (C.H. Wright) Verdc.	Oleaceae	wegeda	Tree
38	*Olea europaea* L. subsp. *cuspidata* (Wall. ex G.Don) Cif	Oleaceae	Woyra	Tree
39	*Olinia rochetiana* A. Juss	Oliniaceae	Tife	Tree
40	*Osyris quadripartita* Decn.	Santalaceae	Qeret	Shrub
41	*Phytolacca dodecandra* L'Herit.	Phytolaccaceae	Endod	Liana
42	*Pittosporium viridiflorum* Sims	Pittosporaceae	weylwiha	Tree
43	*Prunus Africana* (Hook.f.) Kalkm	Rosaceae	Koma	Tree
44	*Rhus glutinosav*A.Rich. subsp. *glutinosa*	Anacardiaceae	Qamo	Tree
45	*Ricinus communis* L.	Euphorbiaceae	Chakima	Shrub
46	*Ritchiea albersii* Gilg.	Capparidaceae	Yetota Kolet	Shrub
47	*Rosa abyssinica* Lindley	Rosaceae	Qega	Shrub
48	*Rubus steudneri* Schwienf.	Rosaceae	Enjori	Liana

Appendix Table 1. Contd.

49	*Rumex nervosus* Vahl	Polygonaceae	Ambacho	Shrub
50	*Rytigynia neglecta* (Hiern) Robyns	Rubiaceae	Dingayseber	Shrub
51	*Schefflera abyssinica* (Hochst. ex A. Rich.) Harms	Araliaceae	Getem	Tree
52	*Solanecio gigas* (Vatke) C. Jeffrey	Asteraceae	Yeshikoko gomen	Shrub
53	*Solanum giganteum* Jacq.	Solanaceae	Tikuir Emby	Shrub
54	*Urera hypselodendron* (A. Rich) Wedd.	Urticaceae	Lankuso	Liana
55	*Vernonia amygdalina* Del	Asteraceae	Girawa	Shrub
56	*Vernonia myriantha* Hook.f.	Asteraceae	Dengorita	Shrub
57	*Zehneria Scabra* (Linn.f.) Sond	Cucurbitaceae	Nech Hareg	Liana

Appendix Table 2. Density, frequency, basal area and IVI of woody plants at Amoro Forest.

S/N	Species	Density (stem/h)	Frequency (%)	Basal area (m^2/ha	Relative density (%)	Relative frequency (%)	Relative dominance (%)	IVI
1	*Acalypha psilostachya*	14.815	27.778	-	0.518	1.618	-	2.136
2	*Acanthus sennii*	13.580	11.111	-	0.475	0.647	-	1.122
3	*Albizia schimperiana*	6.790	13.889	0.018	0.237	0.809	0.100	1.146
4	*Allophyllus abyssinicus*	425.926	88.889	0.992	14.890	5.178	5.367	25.435
5	*Apodytes dimidiata*	18.827	61.111	3.527	0.658	3.560	19.089	23.307
6	*Arundinaria alpina*	117.284	5.556	0.001	4.100	0.324	0.005	4.429
7	*Asparagus africanus*	0.617	2.778	-	0.022	0.162	-	0.183
8	*Bersama abyssinica*	104.630	69.444	0.327	3.658	4.045	1.771	9.474
9	*Bridelia micrantha*	29.938	36.111	0.091	1.047	2.104	0.494	3.644
10	*Brucea antidyssentrica*	73.765	75.000	0.020	2.579	4.369	0.109	7.057
11	*Buddelja polystachya*	10.494	13.889	0.025	0.367	0.809	0.136	1.312
12	*Buddleja davidii*	8.333	13.889	0.013	0.291	0.809	0.068	1.169
13	*Calpurnia aurea*	207.716	58.333	0.014	7.262	3.398	0.074	10.734
14	*Carissa spinarum*	128.704	11.111	0.002	4.499	0.647	0.009	5.155
15	*Clausena anisata*	152.160	44.444	-	5.319	2.589	-	7.908
16	*Clematis longicauda*	0.309	2.778	-	0.011	0.162	-	0.173
17	*Clutia abyssinica*	41.358	11.111	-	1.446	0.647	-	2.093
18	*Croton macrostachyus*	16.358	27.778	0.030	0.572	1.618	0.161	2.351
19	*Discopodium penninervium*	62.037	75.000	0.072	2.169	4.369	0.387	6.925
20	*Dodonaea anguistifolia*	0.926	2.778	0.002	0.032	0.162	0.008	0.202
21	*Dombeya torrida*	10.802	38.889	0.032	0.378	2.265	0.171	2.814
22	*Dovyalis abyssinica*	54.630	44.444	0.064	1.910	2.589	0.348	4.846
23	*Ekebergia capensis*	7.099	33.333	0.339	0.248	1.942	1.837	4.027
24	*Embelia schimperi*	22.840	25.000	-	0.798	1.456	-	2.255
25	*Erythrina brucei*	0.617	5.556	0.005	0.022	0.324	0.028	0.373
26	*Euphorbia abyssinica*	124.074	72.222	0.385	4.338	4.207	2.085	10.630
27	*Ficus sur*	3.704	13.889	0.162	0.129	0.809	0.876	1.814
28	*Juniperus procera*	0.309	2.778	0.001	0.011	0.162	0.006	0.179
29	*Laggera tomentosa*	66.667	25.000	-	2.331	1.456	-	3.787
30	*Lippia adoensis*	0.926	2.778	-	0.032	0.162	-	0.194
31	*Lobelia giberroa*	71.914	38.889	0.015	2.514	2.265	0.079	4.858
32	*Maesa lanceolata*	6.790	13.889	0.015	0.237	0.809	0.081	1.128
33	*Maytenus arbutifolia*	85.494	41.667	0.013	2.989	2.427	0.069	5.485
34	*Maytenus obscura*	3.395	8.333	0.079	0.119	0.485	0.427	1.032

Appendix Table 2. Contd.

35	*Myrsine africana*	23.457	5.556	-	0.820	0.324	-	1.144
36	*Olea capensis*	1.543	11.111	0.548	0.054	0.647	2.968	3.669
37	*Olea europaea*	0.926	5.556	0.044	0.032	0.324	0.240	0.596
38	*Olinia rochetiana*	12.963	25.000	0.029	0.453	1.456	0.156	2.065
39	*Osyris quadripartita*	16.358	25.000	0.006	0.572	1.456	0.031	2.060
40	*Phytolacca dodecandra*	25.000	27.778	-	0.874	1.618	-	2.492
41	*Pittosporum virdiflorum*	0.617	5.556	0.013	0.022	0.324	0.072	0.417
42	*Prunus africana*	55.247	83.333	4.429	1.931	4.854	23.971	30.756
43	*Rhus glutinosa*	28.395	22.222	0.011	0.993	1.294	0.061	2.348
44	*Ricinus communis*	1.235	5.556	0.008	0.043	0.324	0.043	0.409
45	*Ritchiea albersii*	32.099	50.000	0.050	1.122	2.913	0.273	4.308
46	*Rosa abyssinica*	9.568	19.444	0.005	0.334	1.133	0.027	1.494
47	*Rubus steudneri*	40.432	36.111	-	1.413	2.104	-	3.517
48	Rumex nervosus	8.951	16.667	-	0.313	0.971	-	1.284
49	*Rytigynia neglecta*	33.025	52.778	0.023	1.155	3.074	0.123	4.352
50	*Schefflera abyssinica*	15.123	52.778	6.917	0.529	3.074	37.438	41.041
51	*Solanecio gigas*	242.284	63.889	0.025	8.470	3.722	0.133	12.324
52	*Solanum giganteum*	0.309	2.778	-	0.011	0.162	0.001	0.174
53	*Urera hypselodendron*	70.062	66.667	-	2.449	3.883	-	6.333
54	*Vernonia amygdalina*	9.259	19.444	0.040	0.324	1.133	0.215	1.672
55	*Vernonia myriantha*	337.963	94.444	0.086	11.815	5.502	0.464	17.781
56	*Zehneria Scabra*	1.543	2.778	-	0.054	0.162	-	0.216
	Total	**2860.185**	**1713.889**	**18.477**	**100**	**100**	**100**	**299.827**

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Identification of the alternate host plants of the groundnut sucking bug (*Rhyparochromus littoralis* Dist.) in the Sudan savannah agro-ecological zone of Nigeria

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To identify the alternate host plants of the groundnut sucking bug (*Rhyparochromus littoralis* Dist.) an emerging field insect pest of groundnut in the Sudan Savannah Agro-ecological zone of Nigeria, field experiment was carried out over a period of five (5) years (2011 to 2016) in order to investigate the behavior of *R. littoralis* with the aim of developing a strategic control method for this insect pest. The study established *R. littoralis* to be a seasonal pest of groundnut that manifests in high density during the months of September to November causing significant loss to cultivated groundnuts in the field and thereafter, disappears until another harvest period. It was observed that, apart from groundnut, *R. littoralis* depended on other plants over-season for the sustenance of its life cycle, where it sucks sap from the plant, pods or fruits. Prominent crops found to be a haven for the over-seasoning for this insect pest included, cowpea, maize, guinea corn and sesame, while a significant percentage were found under the bark-shelves of live-shea tree. This study therefore recommended serious sanitation measures and good cultural practices of field maintenance to curb the rapid multiplication of this insect pest.

Key words: Alternate host, strategy, over-seasoning, sucking bug, insects, population.

INTRODUCTION

Insects are vital to the immense cycle of life, furnishing food for other creatures and breaking down natural materials to chemicals and nutrients for recycling into new life. Whirling, buzzing, singing, chewing, vibrating

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with energy, they are all around us (Youdewei, 2002). It is only through careful observations that one would be able to understand the behavior of insects. Insects belong to a group of organisms called arthropods, a word that means "jointed feet." Insect bodies are quite variable, but generally adult insects have a few things in common: A head with two antennae, a thorax with six legs and up to two pairs of wings, and an abdomen. In their immature stage, insects are called larvae (caterpillars or grubs) or nymphs (Blay et al., 2000).

Other arthropods, such as spiders, sow bugs, centipedes, ticks and mites may superficially look like insects, but they belong to other animal groups. There are many reasons why insects are so successful at surviving. Their amazing ability to adapt permits them to live in extreme ranges of temperatures and environments (Kalaiyarasan and Palanisamy, 2002). The one place they have not yet been found to any major extent is in the open oceans. Insects can survive on a wide range of natural and artificial foods, pepper, glue, books, grain, cotton, other insects, plants and animals. Because they are -small, they can hide in tiny spaces. A strong, hard but flexible shell called an exoskeleton covers their soft organs and is resistant to chemicals, water and physical impact. Their wings give them the option of flying away from dangerous situations or toward food or mates (Lale, 2002). Also, insects have an enormous reproductive capacity: A honey bee queen lays as many as 4,000 eggs a day, and an African termite queen can lay as many as 43,000 eggs a day. Another reason for their success is the strategy of protective coloration. An insect may be right before our eyes, but nearly invisible because it is cleverly camouflaged like a green leaf, lump of brown soil, gray lichen, a seed or some other natural object. Some insects use bright, bold colors to send warning signals that they taste bad, sting or squirt out poison. Others have wing patterns that look like the eyes of a huge predator, confusing their enemies. Some insects also mimic bitter-tasting insects; hungry foes are fooled into avoiding them (Kalaiyarasan and Palanisamy, 2002).

A remarkable variety of insects inhabit this planet. More species of insects exist than all other animal species together. Insects have survived on earth for more than 300 million years, and may possess the ability to survive for millions more. Insects can be found almost everywhere on the highest mountains and on the bottom of rushing streams, in the cold South Pole and in bubbling hot springs. They burrow through the ground, hop and sing in the trees and dart and dance in the air (Lale, 2002; Wightman et al., 1990). They come in many different colors and various shapes. Insects are extremely useful to humans, pollinating our crops as well as flowers in meadows, forests, deserts and other areas. But ticks and some insects, such as mosquitoes and fleas, can transmit diseases. However, the major field insect pest of groundnut can be grouped as soil inhibiting insects' foliar feeding insect (those that transmit virus diseases) and insects that damage flowers and growing parts (Wightman et al., 1990).

Rhyparochromus littoralis commonly known as Lygaeid bug, or groundnut pod sucking bug, which belongs to the order Heteroptera and family Lygaeidae is found in all groundnut growing areas in Sudan Savannah of Nigeria, where it is known to cause serious damage to groundnut during harvest, but detailed record on history of its over-seasoning strategy remains unknown (Samaila and Malgwi, 2010 and Malgwi and Onu, 2004).

MATERIALS AND METHODS

The study areas

Field observations and experiment were carried out in seven (7) major groundnut producing communities in Adamawa State (Song, Girei, Hong, Ganye, Fufore, Gombi, and Yola South), which lies between the coordinates: 9°20′N 12°30′E; 9.333°N 12.500°E; 9.333; 9° 21.263′; 9° 21.252′; 12°30.234′ and 12°30.251′ East of the Equator in the Northern Guinea Savannah agro-ecological zone of North Eastern Nigeria.

Determination of alternate host plants

To identify the alternate host of the *R. littoralis,* observations were made around the experimental plots to observe the prevalence of the pest on, maize, cowpea and sorghum based, weeds, and sesame plants planted all within 10 to 30 m away from the field experiments. Physical observations were also made on the other possible alternate host like trees, plant debris etc.

RESULTS

Alternate hosts of *R. littoralis*

Alternate host plants of R. littoralis is given in Table 1.

Behaviour, movement and survival strategy of *R. littoralis*

It was difficult to monitor the activity of the bug on groundnut during the day; however, it was observed that at night, the bug is very active; this proved that the insect is nocturnal in nature, since most of its activities were done at night time. It was very difficult to catch the insect both in the daytime and at night at a sound or disturbance, *R. littoralis* will pause just within some seconds, probably to note the direction of disturbance and continuous disturbance makes them crawl quickly or hide under groundnut haulms or fly away.

However, the heavy presence of this bug on under the bark of shea tree suggests that *R. littoralis* might have

Table 1. Alternate host plants of *Rhyparochromus littoralis* Dist Discovered between 2011 and 2016.

S/N	Family	Scientific name	Where the bug is found
1	Acanthaceae	*Asystasia gangetica* (Linn.) T. Anders	Debris of the cultivated crops, road sides and waste areas
2	Asteraceae	*Hyposestes cancellata* Nees	Debris of the cultivated fields and bush fallows
3	Asteraceae	*Justicia flava (*Forsk) Vahl	Compound farms usually growing on moist soils
4	Asteraceae	*Tridax procumbens* Linn	Abundant on lands with debris of this plant on waste areas and road sides
5	Pedaliaceae	*Sesamum orientale* L (*S.indicum* L)	Debris on cultivated oil seed crop.
6	Gramineae	*Zea mays* L	Debris of stalks and leaves of harvested maize especially when harvested green
7	Leguminoseae	*Unguiculata esculentum*	Late maturing varieties and other wild species
8.	Sapotaceae	*Vitellaria paradoxa*	Underneath the bark of live shea tree, where it sucks sap, lay eggs and multiply in very large numbers especially on bigger trunks (for over seasoning strategy)

Source: Field Survey, 2011 – 2016.

been in existence in these areas for a very long time, but was not given attention as a threatening pest. Although no work has been carried out on *R. littoralist* alternate feeding sources, findings in this study could serve as an eye opener on its possible alternate hosts. There is also the need to thoroughly investigate this insect pest which will help in developing a comprehensive control of *R. littoralis*, because the pest appears to survive for longer periods under the bark of the shea tree than any of the identified alternate host plants in all the locations investigated.

The families of the weeds that could serve as alternate host plants has to be put into consideration as most of them other than those found, could be potential host plants or alternate host plants where *R. littoralis* is a dormant pest. Care should be taken that such weeds and crop plants are not planted or rotated on the same field, mix farming or inter cropping where *R. littoralis* is a major pest as stated previously.

Conclusion

The present study confirmed *R. littoralis* as a serious threat to groundnut farming in the study areas and by extension other groundnut producing areas in Nigeria, which is in conformity with the survey conducted by Samaila and Malgwi (2010). This threat should be taken seriously and adequate measures should be taken by the groundnut farmers, researchers, major stakeholders and policy makers to ensure a gradual elimination of this insect pest that appears to hibernate and survive. It is therefore, opined that, the present study has increased greatly the basic knowledge on the over-seasoning strategy of the groundnut sucking bug “Sha mai” or “offa” (*R. littoralis)* thus paving way for a concerted effort in the formation of a strategic management principles for its control and which will, in turn help in controlling other pests of groundnut, as well. The identification of alternate host plants, which serve as source of over seasoning strategy, and the behaviour, and other knowledge of its possible habitat or niches of *R. littoralis* are major steps towards understanding and planning an effective management and control programme for its control and probably eradication. Given the findings of this study, the following are suggestions or recommendations that could be utilized in planning an effective management of *R. littoralis* control and future research:

1. All thrash and debris on the farm should be collected and burnt after harvest. This will assist in breaking the life cycle of *R. littoralis* and that of other insect pests.
2. Groundnut seeds should be obtained from reliable sources treated or dressed before planting.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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