

TAXONOMY OF FALL ARMYWORM (SPODOPTERA FRUGIPERDA J.E. SMITH 1797) INFESTING MAIZE IN THE GUINEA SAVANNA VEGETATION ZONE OF NIGERIA

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ABSTRACT

Taxonomy of Fall Armyworm (Spodoptera frugiperda J.E. Smith 1797) infesting maize in the Southern Guinea Savanna vegetation zone of Nigeria was studied in two States of Niger and Nasarawa as well as Abuja, the Federal Capital Territory (FCT). A total of 1930 Fall Armyworms (FAW) larva were collected from 15 farm locations (farms located) in nine Local Government Areas/Area Councils in the two states and FCT, covering Latitudes (7.8°- 11.3°N and Longitudes 3.2°- 8.8°E). The larvae were bred into adult and both the larva and adult were identified at the Insect Museum of the Department of Crop Protection, Ahmadu Bello University, Zaria. Wing landmarks and body morphometric features were measured with digitalized handheld Miscope microscope 40-140xmag. The mean values of the morphometric feature were 15.58± 1.34 Length of Forewings (LFW), 3.65±0.77 Width of Forewings (WFW), 9.52±0.88 (Length of Hind wings LHW), 2.96±0.38 Width of Hind Wings (WHW), 3.42±0.74 (Total Body Length TBL), 21.71±2.50 (Length of Abdomen LAB), 12.03±6.92 (Width of the Abdomen WAB), 3.04±1.20 (Length of Femur LFE), 3.30±0.46 (Lengths of Tibia LTI) and 3.11±0.86 (Length of Tarsi LTA). The mean Number of Landmark (LNM), Length of Proboscis (PRR) and Antenna (ANT) were 8.33±0.52, 2.02±0.28 and 5.81±1.09 respectively. The findings of this research grouped the Fall Armyworms into one morphoclusters and portrays the use of variations in the wing landmarks and morphometric features of Fall Armyworm as tools that can be adopted for the taxonomy of FAW in the Southern Guinea Savanna vegetation of Nigeria.

Keywords: Fall Armyworm, Southern Guinea Savanna, Taxonomy, Morphometric features, Wing Landmarks

Introduction

Maize (*Zea mays*) production in Savanna vegetation of Nigeria has grown to be a commercial crop servicing (del :) agro-base, medical, pharmaceutical, herbal and related industries (Iken and Amusa, 2004). Findings present maize as having dual role of feeding the fast-growing human population and supporting buoyant agricultural industrialization (Iken and Amusa, 2004). Uses of maize in Nigeria vary in multitude (inappropriate term) of ways. The grain is prepared into Nigerian traditional meal (is it the traditional meal that is used ...) and used

as one of the major feedstuffs in livestock feed formulation (IITA, 2001). IITA also reported that maize leaves, stalks, tassels and cobs are being used for production of a variety of food and non-food products in Nigeria (for humans or animals?).

Comparative morphological analysis is one of the useful tools for the classification of groups of insects. This technique has been used to assist (del.) in identifying many insect species (Barfield and Ashley, 1987, Oyerinde et al., 2012a&b, 2013). The wings of insects have long been known to be a reliable diagnostic

feature for a given species (Wilke et al., 1991). Moreover, wing morphology has historically been a major focus in taxonomic and evolutionary studies of Lepidopteran and Hymenopterans (Berta et al., 2000; Oyerinde et al., 2012a&b).

Farmers across Africa are struggling with the often-devastating spread of Fall Armyworm (FAW), an invasive species from the America that was first observed in West and Central Africa in early 2016 (Georgen et al., 2016). The need to determine the races of FAW in Nigeria is crucial as the invasion of crops has continued to increase since the first outbreak of FAW was reported in Nigeria in January 2016. Also, The influence of geographical/vegetation location on the distribution of FAW, as well as, the impact on crop damage also remains elusive in Nigeria. This study investigates and presents a morphometric classification of FAW (*Spodoptera frugiperda*, J.E.Smith) infesting maize in the Southern Guinea Savanna vegetation zone of Nigeria.

Materials and Methods

Study Sites and Collection of Samples

Random samples of 1930 Fall Armyworm larvae were collected from farms situated in two states and the Federal Capital Territory (FCT) Abuja in the Southern Guinea Savanna vegetation zone of Nigeria. The states were Niger, Nassarawa and the FCT. Sample collection followed a stratified random sampling. Stratification was based on the level of infestation on the farm. Samples of the Fall Armyworm larva collected were divided into two. One part was stored separately in 70% ethanol in a small labeled plastic container according to the location of collection while the other part was bred to adult. Morphometric analysis of the adult and larvae was done to

identify the armyworms at the Insect Museum of the Department of Plant Protection, Faculty of Agriculture, Ahmadu Bello University Zaria.

Collection of larvae

Pitfall insect traps were half filled with ethanol water solution and placed in furrow of ridges to trap the insect. Trapped FAW Adult and larvae were collected weekly,. Some larvae were picked with forceps from maize funnel and foliage. The samples were stored and labelled appropriately in a (del.) plastic vials. All larvae or larva?? were stored in 70% ethanol.

Breeding of the larvae

Larvae collected for breeding were placed in a breeding jar of 250 cm³, covered with muslin cloth for proper aeration and kept for 3 weeks under laboratory condition between 28°C - 34°C for emergence of the adult. It was kept for 3 weeks for adult to emerge.(del). The newly emerged FAW adults were pinned and placed in an insect box (. The sample was used) for further morphometric studies at the Insect Museum of the Department of Crop Protection Ahmadu Bello University, Zaria, Nigeria.

Morphometric Studies

In the Museum, multivariate morphometric analyses were performed on 340 randomly selected bred samples of FAW. This was done by adopting the use of morphometric and wing landmarks variations of the samples. A total of 13 different morphometric features, in line with Hepburn et al., 2005; Michener, 2007; Oyerinde et al., 2012 a&b. were measured. These include:

1. Length of Forewings (LFW),

2. Width of Forewings (WFW),
3. Length Hind wings (LHW),
4. Width of Hind wings (WHW),
5. Total Body Length (TBL),
6. Length of Abdomen (LAB),
7. Width of Abdomen (WAB),
8. Length of Femur (LFE),
9. Tibia? Length of Tibia (LTI),
10. Tarsi? Length of Tarsi (LTA),
11. Proboscis? (PRR) and
12. Antenna (ANT)

(in line with Hepburn et al., 2005; Michener, 2007; Oyerinde et al., 2012 a&b.) del.

Also, The number of wing landmarks revealing points of correspondences between and within the wing vein morphology of FAW was also measured (done)del. in line with procedures by Bookstein, 1991; Dryden and Mardia, 1998; Aytekin et al., 2007; Francoy et al., 2006; 2008 procedures.del.

All measurements were made with the aid of a calibrated handheld digitalized microscope with magnification range of 40-140x in mm.

DATA ANALYSIS

Data obtained from the morphometric and wing landmarks studies were analyzed with SPSS (write in full before abbreviation) Software version 18. The analysis also involved parametric statistical tools of mean, standard deviation and standard error. The distribution and relationship between them

were subjected to two-step and hierarchical cluster analysis. The morphometric means were presented in centroids and the simultaneous confidence intervals (95%) of means were calculated. In addition, the dendrogram plot,del. Coma was computed to illustrate the hierarchical clustering of morphometric and wing landmarks features of the FAW samples. The dendrogram plots of hierarchical cluster analysis results was used to show the phylogenetic relationship of the FAW samples obtained. This allowed classification of the FAW collected from different locations in the Southern Guinea Savanna vegetation of Nigeria.

RESULTS

A total of 1340 Fall Armyworm larvae were collected from maize farms in three Local Government Areas of Niger State (include the longitude and latitude?). 248 and 342 (Don't start a sentence with figures) larvae were collected from farms in three Local Government Areas in Nassarawa State (Longitude 8° 50' E, Latitude 8° 19' N) and farms in three Area Councils of FCT (Longitude 6° 18' E, Latitude 8° 67' N) respectively (Table 1). NB: The Longitudes and Latitudes are not in line with what you have in the abstract pls crosscheck. The write up is not flowing, recast.

Table 1 Distribution of Armyworm Samples Collected from Two States and FCT in the Southern Guinea Savanna Vegetation Zone of Nigeria

S/No	State	Local Government/ Area Council	Farm location	Longitude °E	Latitude °N	Samples collected
1	Niger	Gurara	Lambata	3.201	11.302	150
			Gawu Babangida	3.201	11.302	160
			Izom	3.201	11.302	150
		Suleja	Suleja	3.201	11.30	150
			Maje	3.201	11.301	150
			Madalla	3.201	11.30	150
		Tarfa	Sabon wuse	3.201	11.302	147
			Tarfa	3.201	11.302	143
			Dikko	3.201	11.301	140
2.	FCT	Gwagwalada	Uniabuja	7.17302	8.97983	230
		Kwali	Kwali	6.91536	8.67144	50
		Abaji	Abaji	6.92371	8.15237	62
3	Nasarrawa	Orbi	Orbi	8.56332	8.29302	100
		Nasarrawa eggon	Nasarrawa eggon	8.86473	7.89281	88
		Lafia	Lafia	6.92371	8.88214	60

Your sample sites are not uniform for FCT and Nasarawa. One location per LGA/Area Council in these two states is inadequate. Need to visit three locations per LGA accordingly.

Distribution of Armyworm Infestation among two states and FCT in the Southern Guinea Savanna Vegetation Zone of Nigeria

The distribution of the FAW samples collected from selected farms in two states and FCT in the Southern Guinea Savanna Vegetation Zone of Nigeria shows that the highest armyworm infestation occurred in

Niger State with 69% followed by FCT, 18% while Nassarawa State had the lowest infestation of 13% (Table 2). (This is incomparable since the treatments are not uniform)

Table 2: Distribution of Fall Armyworm (FAW) in Two States and FCT in the Southern Guinea Savanna Vegetation Zone of Nigeria

STATE	FREQUENCY	% DISTRIBUTION
FCT	342	18 %
Nassarawa	248	13 %
Niger	1340	69 %
Total	1930	100 %

The figures under frequency are the total number of larva collected under results, pls find appropriate caption

Morphometric Studies

A total of 13 different morphometric features measured on the selected FAW from two states and FCT in the Southern Guinea Savanna vegetation zone of Nigeria gave variations drawn into centroid (Table 3).

1. The mean value of the length of forewings (LFW) was 15.58 ± 1.34 ,
2. the mean value of the width of forewings (WFW) was 3.65 ± 0.77 ,
3. the average length of hind wings (LHW) was 9.52 ± 0.88 while
4. the average width of hind wings was 2.96 ± 0.38 .
5. The mean value of the total body length (TBL) was 3.42 ± 0.74 whereas
6. the mean length of abdomen (LAB) was 21.71 ± 2.50 .
7. The mean width of the abdomen (WAB) was 12.03 ± 6.92 .
8. The mean length of femur (LFE) was 3.04 ± 1.20 while
9. while the mean lengths of Tibia (LTI) was 3.30 ± 0.46 and
10. Length of Tarsi (LTA) was 3.11 ± 0.86 ,
11. The mean values of landmark (LNM) was 8.33 ± 0.52 ,
12. Proboscis (PRR?) was 2.02 ± 0.28 and (PRR and proboscis did not tally)
13. Antenna (ANT) was 5.81 ± 1.09 .

Table 3: Morphometric features of Fall Armyworm in Two States and FCT in the Southern Guinea Savanna Vegetation Zone of Nigeria

Cluster	LFW		WFW		LHW		WHW		TBL		LAB		WAB		LFE		LTI		LTA		LNM		PRR		ANT	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	15.58	1.34	3.65	0.77	9.52	0.83	2.96	0.38	3.42	0.74	21.71	2.50	12.03	6.92	3.04	1.20	3.30	0.46	3.11	0.86	8.33	0.52	2.02	0.28	5.81	1.09
Combined	15.58	1.34	3.65	0.77	9.52	0.83	2.96	0.38	3.42	0.74	21.71	2.50	12.03	6.92	3.04	1.20	3.30	0.46	3.11	0.86	8.33	0.52	2.02	0.28	5.81	1.09

Key: Length of Forewing (**LFW**), Width of Forewing (**WFW**), Length of Hind wing (**LHW**), Width of Hind wing (**WHW**), Total Body Length (**TBL**), length of abdomen (**LAB**), width of abdomen (**WAB**), Length of Femur (**LFE**), Length of Tibia (**LTI**), Length of Tarsi (**LTA**), Landmarks (**LNM**), Proboscis (**PRR**), Antenna(**ANT**).

Cluster Analysis

Two step cluster analysis was performed on sixty adults reared FAW from two states and FCT in the Southern Guinea Savanna vegetation zone of Nigeria. The chosen clusters are the categorical variables (location)

and the continuous variable (morphometric features) of the insects. The cluster distribution frequencies are presented in Table 4. All the FAW collected from different states and the FCT were of single morphocluster and that shows that they were of the same descent.

Table 4. Cluster Distribution Frequencies of Fall Armyworm from Two States and FCT in the Southern Guinea Savanna Vegetation Zones of Nigeria

Location		Federal Capital Territory/FCT		Nasarawa/Nas		Niger/Nig	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Cluster	1	140	100.0%	100	100.0%	100	100.0%
	Combined	140	100.0%	100	100.0%	100	100.0%

Dendrogram Plot

The dendrogram plot generated (Figure 1) from average linkage also grouped the FAW into one cluster based on the states and FCT. The Dendrogram revealed linkages between the different samples collected from the two states and FCT. This gives an indication that the samples or larva? were of the same descent based on morphometric and wing

landmarks features and portrays that the variations in morphometric features and wing landmarks can be engaged in classifying FAW in the Southern Guinea Savanna vegetation zone of Nigeria.

Dendrogram using
Average Linkage (Between Groups). Rescaled
Distance Cluster Combine

*****HIERARCHICAL CLUSTER ANALYSIS**

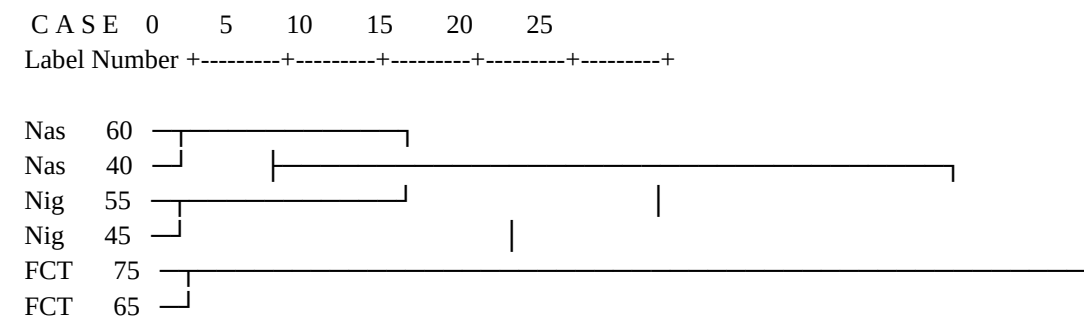


Figure 1. Dendrogram using Average Linkages of Species from Two States and FCT in the Southern Guinea Savanna zone of Nigeria.

DISCUSSION

Results obtained from this study revealed that Fall Armyworm infestation in the Southern Guinea Savanna vegetation zones of Nigeria was adverse and could significantly affect farmers (or affect yield) in the area (Durjadin, 2008, 2011). Wing size is known to be easily affected by environmental factors (Gomez et al., 2014) and the results obtained clearly showed that wing size cannot be used to separate the FAW infesting maize in the Southern Guinea Savanna vegetation zone of Nigeria. In contrast, wing shape showed to be a stable character compared to size (Lyra et al., 2010; Lorenz et al., 2012; Jaramilo et al., 2015) and very informative on the phylogenetic and evolutionary relationship of organisms (Bookstein, 1991). Therefore, it was not surprising to see that the morphometric results supported that wing shape and landmarks could be used to separate the Fall Armyworm species of the Southern Guinea Savanna vegetation zone of Nigeria, not only at the genus level but also at the species level. However, the latter (write down what the latter represent) depends on the genus to which the species belongs. (Zajac et al., 2016).

However, it is not surprising that wing shape of most of the species overlaps. The same pattern is seen (del.) using morphology to distinguish among the FAW species is very difficult because most of them look alike. (Different, start a new sentence) and about molecular data, several studies have shown that FAW species have low inter-specific variation among closely related species (DeBry et al., 2013). In this regard, using a landmark-based characterization of wing morphology is a reliable technique for

classifying FAW species in the Southern Guinea Savanna vegetation zone of Nigeria, but a much less precise technique to separate the species. The large overlapping among species within the Spodoptera shows that wing shape between species is very similar to each other. Therefore, using wing morphometric analysis for species identification within FAW should be performed in combination with additional morphological methods for accurate species identification. Nevertheless, this study demonstrates that a landmark-based analysis of wing morphometry can be a good tool for identification of FAW. This conforms to previous studies on South American taxa (Vasquez and Lina, 2012) and *Cochliomyia hominivorax* and *Cochliomyia macellaria* ?? (Lyra et al., 2010).

The cluster analysis using dendrogram based on the wing and body morphology of the 340 FAW species clearly placed all species into their respective subfamily. The phenotypic relationships between species detected were in accordance with molecular phylogenetic tree (Zajac et al., 2016). Such a result suggests that wing morphology could detect some phylogenetic signal in FAW. Thus, a landmark-based morphometric analysis of wings and body could be used as a valuable tool in taxonomy of insects. In comparison with molecular techniques, a landmark-based analysis of wing and body morphology is simple, reliable and inexpensive, and just requires non-damaged wings and body for analysis. Although wing landmark and morphometric features-based analyses can be a time-consuming process, but they are simple and highly reliable (Arnquist and Martenssen, 1998, Dujardin, 2011; Hall et al., 2014)

CONCLUSION

The results demonstrated that a landmark and morphometric features-based analyses of wings and body could be used to (for) classification of Fall Armyworm infesting maize in the Southern Guinea Savanna vegetation zone of Nigeria at both genus and species levels. Using wing landmarks was a highly reliable method for classifying FAW species. The use of morphometric analysis could be an alternative method used for both

species and sex discrimination (Did you work on sex ...) In addition, the congruence between morphometric analysis in this study and molecular phylogenetic tree from previous studies (write down the previous studies), suggest that morphology is a valuable tool that can be adopted in taxonomy of Fall Armyworm species in the Southern Guinea Savanna vegetation zone of Nigeria.

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Example of correct reference form is given as follows:

Reference to a journal publication:

Olafadehan, O.A., Oluwafemi, R.A. and Alagbe, J.O. (2020). Performance, haemato-biochemical

parameters of broiler chicks administered Rolfe (*Daniellia oliveri*) leaf extract as an antibiotic alternative. Advances in Research and Reviews. 1(4): 56-65.

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