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GLOBAL JOURNAL OF SCIENCE FRONTIER RESEARCH: D
AGRICULTURE & VETERINARY SCIENCES

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AGRICULTURE & VETERINARY SCIENCES

VOLUME 12 ISSUE 7 (VER. 1.0)

OPEN ASSOCIATION OF RESEARCH SOCIETY

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Effect of Moisture, Bulk Density and Temperature on Thermal Conductivity of Ground Cocoa Beans and Ground Sheanut Kernels

By A. Bart-Plange, A. Addo, S. K. Amponsah & J. Ampah

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Abstract - Thermal conductivity is an important engineering parameter in the design of food processing equipment. It predicts or controls the heat flux in food during processing such as cooking, frying, freezing, sterilization, drying or pasteurization. The thermal conductivity of ground cocoa beans and ground sheanut kernels with varying moisture content, bulk density and temperature was studied using the transient heat transfer method. The thermal conductivity increased linearly for ground cocoa beans sample from 0.0243 to 0.0311 W/oCm and for ground sheanut kernels from 0.0165 to 0.0458 W/oCm in the moisture content range of 12.59 to 43.84 % w.b. at a constant bulk density of 295 kg/m³. For bulk density range of 322 to 410 kg/m³, thermal conductivity of ground cocoa beans and ground sheanut kernel increased linearly from 0.0265 to 0.0324 W/oCm and 0.0209 to 0.0252 W/oCm respectively when moisture content was at 16 % w.b Thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0233 to 0.0382 W/oCm and 0.0261 to 0.0397 W/oCm respectively as temperature increased from 35 to 55 oC. Effect of moisture, bulk density and temperature on thermal conductivity of sheanut kernel and cocoa bean were found to be significant ($p > 0.05$).

Keywords : Thermal conductivity, sheanut, kernels, cocoa beans, moisture content, bulk density, temperature.

GJSFR-D Classification : FOR Code: 070399



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Effect of Moisture, Bulk Density and Temperature on Thermal Conductivity of Ground Cocoa Beans and Ground Sheanut Kernels

A. Bart-Plange ^α, A. Addo ^σ, S. K. Amponsah ^ρ & J. Ampah ^ω

Abstract - Thermal conductivity is an important engineering parameter in the design of food processing equipment. It predicts or controls the heat flux in food during processing such as cooking, frying, freezing, sterilization, drying or pasteurization. The thermal conductivity of ground cocoa beans and ground sheanut kernels with varying moisture content, bulk density and temperature was studied using the transient heat transfer method. The thermal conductivity increased linearly for ground cocoa beans sample from 0.0243 to 0.0311 W/°Cm and for ground sheanut kernels from 0.0165 to 0.0458 W/°Cm in the moisture content range of 12.59 to 43.84 % w.b. at a constant bulk density of 295 kg/m³. For bulk density range of 322 to 410 kg/m³, thermal conductivity of ground cocoa beans and ground sheanut kernel increased linearly from 0.0265 to 0.0324 W/°Cm and 0.0209 to 0.0252 W/°Cm respectively when moisture content was at 16 % w.b. Thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0233 to 0.0382 W/°Cm and 0.0261 to 0.0397 W/°Cm respectively as temperature increased from 35 to 55 °C. Effect of moisture, bulk density and temperature on thermal conductivity of sheanut kernel and cocoa bean were found to be significant ($p > 0.05$).

Keywords : Thermal conductivity, sheanut, kernels, cocoa beans, moisture content, bulk density, temperature.

I. INTRODUCTION

Sheanut and Cocoa are important oil producing crops in Ghana. Sheanut hails from the *Sapotaceae* family. The commonly known varieties include *Vitellariaparadoxa* (*Butryospermum parkii*) and *Vitellarianilotica*. Shea nut is obtained from the shea tree, and is grown mostly throughout West and Central Africa; in the semiarid Sahel from Senegal to Ethiopia (Aremu and Nwannewuihe, 2011). Shea nut contains reasonably high amounts of oleic acids from which the shea butter (fat) is obtained. Shea butter is one of the basic raw materials for most food, cosmetics, soap as well as the pharmaceutical industries (Thioune et al., 2000) and it is sometimes used as a substitute for cocoa butter (Bekure et al., 1997).

Cocoa (*Theobroma Cacao*) is an ancient crop of the lowland tropical forest, which originated from the

Southern and Central America (Lefeber et al., 2011). In West Africa, cocoa is one of the most important cash crops. Globally, Ghana's cocoa bean production is ranked second in the world after her western neighbour Côte d'Ivoire (FAOSTAT, 2005). Ghana is recognized as the world leader in premium quality cocoa beans production. Cocoa serves as the major source of revenue for the provision of socio-economic infrastructure in the country. In terms of employment, the industry employs about 60% of the national agricultural labour force in the country (Appiah, 2004 cited in Ntiamoah and Afrane, 2008). For these farmers, cocoa contributes about 70 -100% of their annual household incomes (COCOBOD, 2004 cited in Ntiamoah and Afrane, 2008). Cocoa seeds are the source of commercial cocoa beans and cocoa products include cocoa liquor, cocoa butter, cocoa cake and cocoa powder as well as chocolate. Cocoa powder is essentially used as flavour in biscuits, ice cream and cakes and is consumed by most beverage industries. Besides the traditional uses in chocolate manufacture and confectionery, cocoa butter, like shea butter, is also used in the manufacture of cosmetics. It is also a folk remedy for burns, cough, dry lips, fever, malaria, rheumatism and wounds. Studies show that the cocoa bean contains flavonoids with antioxidant properties that can reduce blood clot and the risk of stroke and cardiovascular attacks (ICCO, 2011).

The thermal conductivity of materials can be influenced by a number of factors such as the moisture content of the material, porosity and fibre orientation of the material (Stroshine and Hamann, 1994; Mohsenin, 1990). Thermal conductivity of food and biological materials increase with increase in moisture content and density (Opoku et al., 2006 for hay; Muramatsu et al. 2006 for brown rice, Aviara et al., 2008 for guna seeds and Perusella et al., 2010 for banana). Thermal conductivity data is needed for calculating energy demand for the design of equipment and optimization of thermal processing of foods (Polley et al., 1980). It controls the heat flux in food during processing such as cooking, frying, freezing, sterilization, drying or pasteurization. In the determination of thermal conductivity of food materials, the commonly employed methods are the transient and the steady-state methods (Mohsenin, 1980). Besides processing and preservation,

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thermal conductivity and other properties such as specific heat and thermal diffusivity also affect sensory quality of foods as well as energy saving during processing (Opoku et al., 2006). It is not uncommon to see farmers dry their produce without taking into consideration the quantity of heat needed to accomplish the drying process which in turn affects the market value of the end product. This is because such information on thermal conductivity of local agricultural products is either unavailable or inadequate.

The objective of this study therefore, was to determine the thermal conductivity of ground sheanut kernel and ground cocoa beans and investigate their dependence on moisture content, bulk density and temperature using the transient heat method.

II. MATERIALS AND METHODS

a) Sample Preparation

The samples were cleaned by removing foreign materials and damaged kernels or beans. Sheanut kernel and cocoa beans had all the quality checks performed and ready for local and export market. Both samples were conditioned to four moisture content levels of 12.59, 22.41, 31.55 and 43.84% wet basis. The samples were sealed in separate polythene bags and kept in a refrigerator at 5°C for five days to ensure uniform moisture distribution. The amount of distilled water added was calculated using equation (1) (Balasubramanian, 2001).

$$M_w = \frac{M_i(m_f - m_i)}{100 - m_f} \quad (1)$$

where:

M_w is the mass of distilled water (g),

M_i is the initial mass of sample (g),

m_f is the final moisture content of sample (%w.b.) and

m_i is the initial moisture content of sample (%w.b.).

For bulk density variation samples were milled in a laboratory hammer mill to a particle size of two millimetres using a set of screen. Varying bulk densities of 322, 346, 381 and 410 kg/m³ were obtained by compressing in a cylinder with known weights at a constant moisture content using standard procedures (AOAC, 2002).

b) Experimental Setup

The setup for the thermal conductivity measurements is shown in Figure 1. The thermal conductivity apparatus is a set-up consisting of an aluminium cylinder with a heating coil stretching between two insulated ends of the cylinder. A thermocouple was fitted through the top end of the cylinder for temperature readings in the sample. Heat source (Q) was supplied by a constant direct current power source with current and voltage of 1A and 3V

respectively throughout the experiment. In the set-up, there was an ammeter to take current readings, voltmeter to take voltage readings and a rheostat to vary resistance in the circuit in order to achieve the desired current.

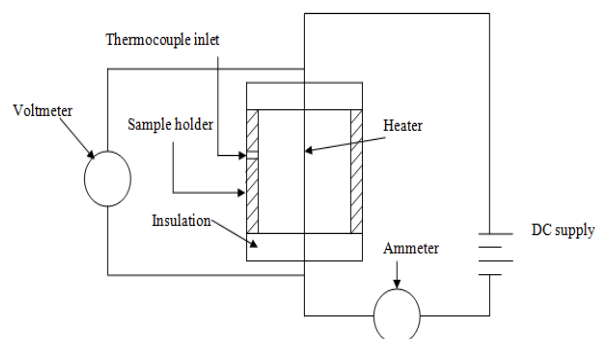


Figure 1 : Schematic diagram of the thermal conductivity measuring apparatus

The conditioned samples were placed in the aluminium sample cylinder in the set-up. The sample temperature at the centre of the cylinder was checked by means of a thermocouple, the current was adjusted to one ampere and a voltage of three volts was used. Temperature readings were taken at regular time interval of one minute for 40 minutes for each sample experimented. Thermal conductivity was determined at five sample temperatures of 35, 40, 45, 50 and 55°C.

c) Thermal Conductivity Determination

Thermal conductivity (k) was determined using equation (2) (Tabil, 1999).

$$k = \frac{Q}{4\pi(t_2 - t_1)} \ln \frac{\theta_2}{\theta_1} \quad (2)$$

where:

$Q = VI$ (V is the supplied voltage, I is input current, heat source per meter of the line source)

k = thermal conductivity of the medium (W/°Cm)

t_1 is initial temperature (°C)

t_2 is final temperature (°C)

θ_1 is initial time (min)

θ_2 is initial time (min)

The thermal conductivity values of the ground sheanut kernel and ground cocoa beans were determined by calculating the slopes of the graphs of temperature changes against time ratio on a semi-logarithm graph. The experiment was replicated four times at each moisture content, bulk density and temperature level and thermal conductivity was recorded in each case.

d) Statistical Analysis

The experimental design used was the completely randomized design (CRD) with single factor

analysis of variance (ANOVA) for all data and analyzed with Minitab Version 15. Statistical significance was carried out using Tukey and Fisher's approach at $p < 0.05$.

III. RESULTS AND DISCUSSION

a) Effect of Moisture Content

Figure 2 shows the linear variation of thermal conductivity of ground sheanut kernel and ground cocoa beans with moisture content at constant bulk density (295 kg/m^3). Thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0165 to $0.0458 \text{ W/}^\circ\text{Cm}$ and 0.0243 to $0.0311 \text{ W/}^\circ\text{Cm}$ respectively with increasing moisture content from 12.59 to $43.84 \text{ \%w.b.}$

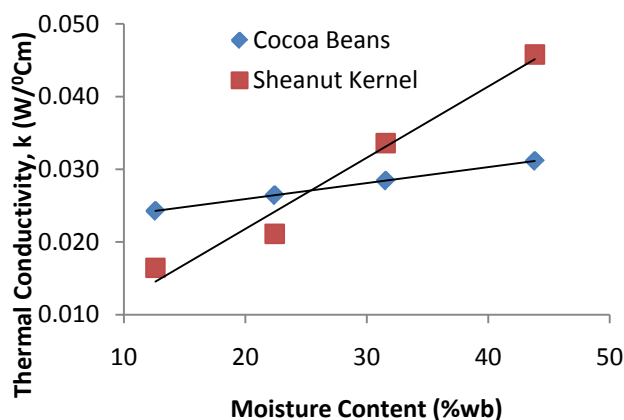


Figure 2 : Thermal conductivity as a function of moisture content

Similar trend was observed in the thermal conductivity of soybean (Deshpande et al., 1996), cumin seed (Singh and Goswami, 2000), sheanut kernel (Aviara and Haque, 2001), borage seed (Yang et al., 2002), millet grains (Subramanian and Viswanathan, 2003), rough rice (Yang et al., 2003), brown rice (Muramatsu et al., 2006), maize and cowpea (Bart-Plange et al., 2009) and guna seed (Aviara et al., 2008).

The increase in thermal conductivity with moisture content can be attributed to the fact that an increase in moisture content of the sample increases the amount of water molecules available to fill the pores within the sample thus increasing the ability of the sample to conduct more heat.

The relationship between the thermal conductivity of ground sheanut kernel (k_{sk}) and ground cocoa beans (k_{cb}) and moisture content (M) can be expressed using equations (3) and (4) respectively.

$$k_{sk} = 0.097M + 0.002, \quad R^2 = 0.974 \quad (3)$$

$$k_{cb} = 0.022M + 0.021, \quad R^2 = 1 \quad (4)$$

Equations (3) and (4) depict that thermal conductivity of ground sheanut kernel and ground

cocoa beans have a linear relationship with moisture content. This agrees with what was reported by Aviara and Haque, (2001) on sheanut kernel. Studies by other researchers also found thermal conductivity to increase with increasing moisture content (Sweat, 1974; Rao and Rizvi, 1986; Mohsenin, 1990; Tansakul and Lumyong, 2008; Meghwal and Goswami, 2011).

b) Effect of Bulk Density

The variation of thermal conductivity of ground sheanut kernel and ground cocoa beans with bulk density at constant moisture content ($16 \text{ \%w.b.}$) is shown in Figure 3.

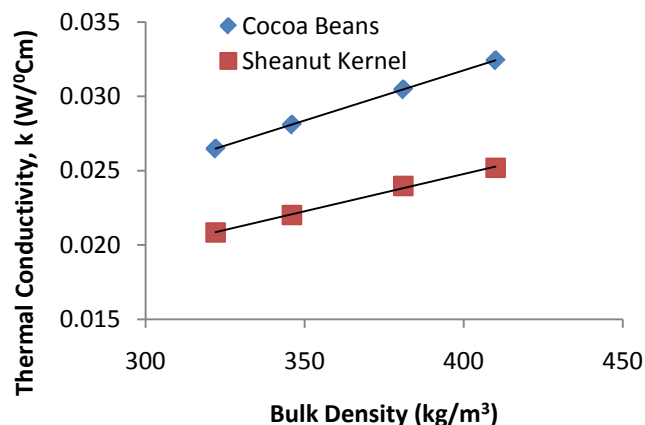


Figure 3 : Thermal conductivity as a function of bulk density.

The thermal conductivity of ground sheanut kernel and cocoa beans increased linearly and significantly ($p < 0.05$) from 0.0209 to $0.0252 \text{ W/}^\circ\text{Cm}$ and 0.0265 to $0.0324 \text{ W/}^\circ\text{Cm}$ respectively as bulk density increased from 322 to 410 kg/m^3 . This trend was similarly observed by other researchers including Taiwo et al (1996) for cowpea, Aviara and Haque (2001) for sheanut kernel, Bart-Plange et al. (2009) for maize and cowpea and Meghwal and Goswami (2011) for black pepper. Moreover, it was observed that the thermal conductivity of ground sheanut kernel was generally lower than ground cocoa beans with increase in bulk density. The increase in thermal conductivity with bulk density can best be explained by making reference to the conduction ability of the sample particles in relation to the pores between them. Increasing the bulk density means increasing the number of particles in a constant volume thus decreasing the pore volume which leads to increased heat conduction ability of the sample.

The linear relationship between the thermal conductivity of ground sheanut kernel (k_{sk}) and ground cocoa beans (k_{cb}) and bulk density (ρ) may be expressed using equations (5) and (6) respectively.

$$k_{sk} = 5 \times 10^{-5}\rho + 0.004, \quad R^2 = 0.997 \quad (5)$$

$$k_{cb} = 7 \times 10^{-5}\rho + 0.004, \quad R^2 = 1 \quad (6)$$

c) Effect of Temperature

Figure 4 describes the variation of thermal conductivity with increasing temperature at constant moisture content and bulk density. At constant moisture content of 20.5 %w.b. and constant bulk density of 420 kg/m³, the thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0233 to 0.0382 W/°Cm and 0.0261 to 0.0397 W/°Cm respectively as temperature increased from 35 to 55 °C.

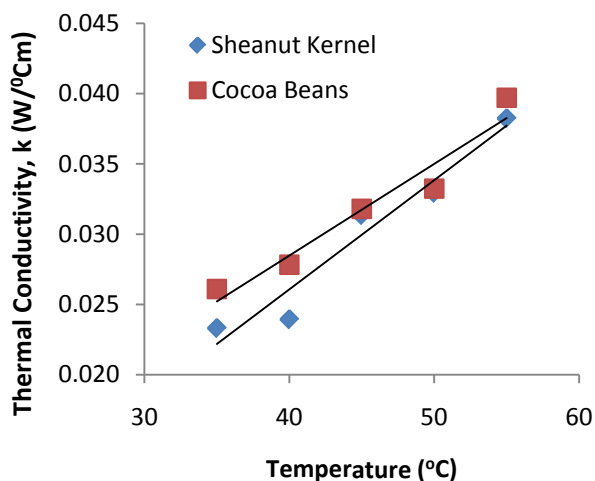


Figure 4: Thermal conductivity as a function of temperature

The linear relationship between the thermal conductivity of ground sheanut kernel (k_{sk}) and ground cocoa beans (k_{cb}) and temperature (°C) can be expressed using equations (7) and (8) respectively.

$$K_{sk} = 0.0008x - 0.005 \quad R^2 = 0.9446 \quad (7)$$

$$K_{cb} = 0.0007x + 0.0024 \quad R^2 = 0.9434 \quad (8)$$

Aviara and Haque (2001) and Bart-Plange et al. (2009) observed an increase in thermal conductivity with temperature for sheanut kernel and maize and cowpea respectively. Kurozawa et al. (2008) found thermal conductivity to increase from 0.57 to 0.61 W/m °C with temperature in the range of 25 to 45 °C for cashew apple. Mahmoodi and Hosein (2008) also found thermal conductivity of pomegranates to increase linearly from 0.6106 to 0.6372 W/m°C with increase in temperature from 26.5 to 45°C.

IV. CONCLUSION

Investigations on the thermal conductivity of ground sheanut kernel and ground cocoa beans revealed the following:

1. Thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0165 to 0.0458 W/°Cm and 0.0243

to 0.0311 W/°Cm respectively with increasing moisture content from 12.59 to 43.84 %w.b. at constant bulk density. A linear relationship was found to exist between thermal conductivity and moisture content.

2. Thermal conductivity of ground sheanut kernel and cocoa beans increased significantly ($p < 0.05$) from 0.0209 to 0.0252 W/°Cm and 0.0265 to 0.0324 W/°Cm respectively as bulk density increased from 322 to 410 kg/m³ at constant moisture content. A linear regression best describes the relationship between thermal conductivity and bulk density.
3. At constant moisture content of 20.5 %w.b. and constant bulk density of 420 kg/m³, the thermal conductivity of ground sheanut kernel and ground cocoa beans increased significantly ($p < 0.05$) from 0.0233 to 0.0382 W/°Cm and 0.0261 to 0.0397 W/°Cm respectively as temperature increased from 35 - 55 °C.

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Computation of Water-Stress Ratio in Western Nigeria

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Abstract - An increasing world population exerts a continually growing demand on usable freshwater resources. Access to water plays a key role in development; it supports human life in direct consumption, agricultural uses and industrial activities. Time and drudgery involved to access safe drinking water resulted to loss of human resources and capital, thus affecting nearly every household life. This paper focuses on the determination of water-stressed ratio using Integrated Water Measurement Tool (IWMT). Structured simple time analysis and Adjusted composite index approaches were employed to compute (IWMT) values in all the sampled areas. Variables such as access to safe water coverage, water availability and use of water were considered. IWMT values from the two approaches show that Ese-Odo is the most water-scarce region with least IWMT values of 14.1 (Adjusted composite index: ACI) and highest value of 2.6 minsl-1 (Structured simple time analysis: SSA), while Owo, Ondo-West and Ose local government areas experience fair distribution of protected water supply with IWMT values of 1.05 minsl-1, 20.8; 1.00 minsl-1, 17.2; and 0.55 minsl-1, 16.9 respectively.

Keywords : *IWMT, index, water stress, safe water, access, water-scarce, uses, household, ACI, SSA, ratio.*

GJSFR-D Classification : *FOR Code : 050101, 060204, 090409, 880206*



COMPUTATION OF WATER-STRESS RATIO IN WESTERN NIGERIA

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Computation of Water-Stress Ratio in Western Nigeria

P. O Idogho^α & Olotu Yahaya^σ

Abstract - An increasing world population exerts a continually growing demand on usable freshwater resources. Access to water plays a key role in development; it supports human life in direct consumption, agricultural uses and industrial activities. Time and drudgery involved to access safe drinking water resulted to loss of human resources and capital, thus affecting nearly every household life. This paper focuses on the determination of water-stressed ratio using Integrated Water Measurement Tool (IWMT). Structured simple time analysis and Adjusted composite index approaches were employed to compute (IWMT) values in all the sampled areas. Variables such as access to safe water coverage, water availability and use of water were considered. IWMT values from the two approaches show that Ese-Odo is the most water-scarce region with least IWMT values of 14.1 (Adjusted composite index: ACI) and highest value of 2.6 minsl⁻¹ (Structured simple time analysis: SSA), while Owo, Ondo-West and Ose local government areas experience fair distribution of protected water supply with IWMT values of 1.05 minsl⁻¹, 20.8; 1.00 minsl⁻¹, 17.2; and 0.55 minsl⁻¹, 16.9 respectively. The results obtained indicate that constructive investments in water and sanitation would reduce proportion of household income spent in sourcing for safe drinking water, prevention of water-related diseases and in turn improves productivity. However, this paper concludes that top-down technical approach in resolving water resources must be balanced with a bottom-up mechanism in order to prevent persistent water scarcity, shortage and to draw realistic adaption measures.

Keywords : IWMT, index, water stress, safe water, access, water-scarce, uses, household, ACI, SSA, ratio.

I. INTRODUCTION

During the last few years, water has become an increasingly important issue in industrialized and developing nations. In order to attain the Millennium Development Goals of halving the population of people without access to safe water by 2015, integrated water management approaches are required (IWMT). In monitoring the achievement of portable water at the local level, appropriate indicators are However this situation is very complex to explain in a simple language, therefore an index has been found to be a feasible way to express such complex condition (Steven *et al.*, 2002). The Water Poverty Index (WPI) was identified as the possible indicator for monitoring progress at the local level as it puts access to water in a

wider water-related context (Sullivan 2000, 2002). The index has been designed to identify and evaluate poverty in relation to water resource availability (Steven *et al.*, 2002). Water shortages may relate to the inadequate ability of society to access the small volumes of water needed for drinking and domestic purposes. In most cases in developing world where they are water-stressed, women and children particularly girls spend most of their productive time trekking long distances sourcing for water. Public health systems are over-burdened by diarrhoeal diseases- the UN says that at any time; half the hospital beds in the developing world are occupied by patients suffering from diarrhoea and other water related ailments. (UNDP, 2004).

In analysing the reasons for water problems, it is important to recognise that water scarcity can be considered in two ways. First order scarcity is the shortage of water itself, while second order scarcity is that resulting from lack of social adaptive capacity. The poor lack social adaptive capacity and this suggests that this aspect of development in the water sector is most pertinent to poverty alleviation (Sullivan *et al.*, 2001).

Having technically evaluated water constraint globally, mostly in developing nations, this research study is designed and developed to test, validate and calibrate existing water-stressed model by applying Integrated Water Measurement Tool (IWMT). Adjusted Composite Index (ACI) and Structured Simple Time Analysis (SSA) are integrated components of IWMT model. These components are very flexible and allow incorporation of many water variables. IWMT model will be established to run all the data obtained in all eighteen local government areas in Ondo-State, Nigeria.

II. MATERIALS AND METHODS

a) Study Area

Ondo State is made up of 18 Local Government Areas is located in the Southwestern Zone of Nigeria. The state lies between longitudes 4°30" and 6° East of the Greenwich Meridian, 5° 45" and 8° 15" North of the Equator. This means that the state lies entirely in the tropics. Ondo State is bounded in the North by Ekiti/Kogi States; in the East by Edo State; in the West by Oyo and Ogun States, and in the South by the Atlantic Ocean. **Land Area:** 14,788.723 Square Kilometres (km²). **Population:** 3,441,024 comprising 1,761,263 Males and 1,679,761 Females.

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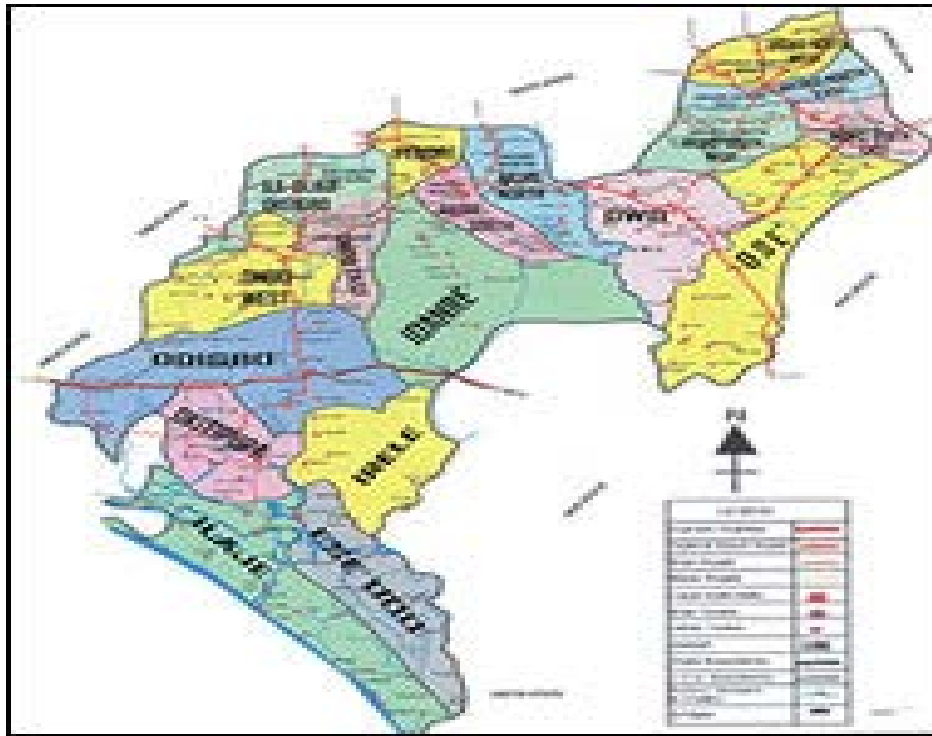


Figure 1. Map of Ondo State showing investigation locations.

I. The Composite Index Approach

In this approach, the index was constructed from a series of variables which captured the essence of what is being measured using national scale (Rodiya, 2007). A simple relationship was constructed for computing WPI taking into consideration all the key variables as follows:

$$SWPI = W_a A + W_s S + W_t (100 - T) \quad (1)$$

Where A is the adjusted water availability (%). The value of A should recognize the seasonal variability of water availability, S is the population with access to safe water and sanitation (%) and T is the index to represent time and effort taken to collect water for the household and WPI is the water poverty index. For the purpose of this study, (T) was modified to take account of gender and child labour issues as follows: (100-T). Since A, S, T are all defined to be between 1 and 100; W_s , W_t is 0.25 by weight and W_a is given 0.5. Therefore,

$$W_a + W_s + W_t = 1.0 \quad (2)$$

The relationship in equation (1) is finally modified as follows:

$$SWPI = \frac{1}{3} [W_a A + W_s S + W_t (100 - T)] \quad (3)$$

where W_a , W_s and W_t are the weight given to A, S and T respectively.

b) Adjusted Composite Index

Equation (3) above does not have capacity to contain all the veritable water variables. The relationship

is further adjusted as follows:

$$IWMT = \frac{1}{3} [W_a A + 0.53C + W_s S + 0.9D + W_t (100 - T)] \quad (4)$$

Where C and D are the adjusted water variables for the developing nations. These range between (0-1.0) depending on the water situation of such community.

c) Simple Time Analysis Approach

WPI is constructed using bottom-up approach considering variables such as total time taken in collecting water including queuing time, volume of water collected in each trip. For the household with pipe borne water, the volume and time taken to collect water per head is assumed to be the same across the members of the household. Using time-analysis approach, the index is determined as follows:

$$SWPI = \frac{T}{V} (\text{min } sl^{-1}) \quad (5)$$

Where T is the total time (in minutes) spent per person in a day to collect water, while V is the volume of water collected in litres. In addition, the expression in equation (5) does not take in consideration of the time spent to travel to and fro for an individual to source/gather water. The time considered is the total time spent for queuing processes. Based on this discovery, equation (5) is adjusted as follows:

$$SSA = 1.86C \frac{T}{V} (\text{min } sl^{-1}) \quad (6)$$

Where C is the correcting factor that is used to

address the total time taken to gather water; this factor is almost *unity*.

Based on a reconnaissance survey of eighteen local government areas in Ondo-State, ten most water-stressed communities in each of the local government areas were randomly selected for sampling purposes. 180 questionnaires were randomly administered to 18 households in each of the 100 sampled communities in all the local government areas. Data were obtained, tested and validated using the relationship in equation 3, 4, 5 and 6. Overall results were compared to draw conclusive resolutions.

III. RESULTS AND DISCUSSIONS

a) Computational analysis of Integrated Water Measurement Tool (IWMT) using Adjusted Composite Index(ACI) and Structural Simple Time Analysis (SSA).

Data were collected from 100 most water-stressed in all the local government areas in Ondo-State, WPI values were calculated using composite index and simple time analysis approaches. The summary of the dataset, showing means of total volume of water collected (T_v), total time spent to collect water (T_T) and Local Government Areas (LGA), is presented in Tables 1 and 2. The Tables showed that Ese-Odo local while Ondo-West has the least value of 0.8 $mins^{-1}$, government has the highest value of IWMT (2.2 $mins^{-1}$), during the wet season as presented in Table 1. It was also found that Ese-Odo local government still recorded

highest IWMT value of 2.6 $mins^{-1}$, while Ose local government has the lowest IWMT value of 0.9 $mins^{-1}$ during the dry season as presented in Table 2. This simple analysis showed that Ese-Odo local government is the most water-stressed region in Ondo State followed by Ilaje, while water stress was considered to be least at Ondo-West and Ose local government during wet and drying seasons respectively. During the consultation process, it was discovered that the dwellers derived their drinking water from a variety of sources such as; direct withdrawal from pond, streams and river, traditional wells of up to 1.5-2.0 m diameter with local construction, modern wells that are usually filled with concrete in order to prevent outside contamination and seepage flow and reticulated solar-powered boreholes of cleaner and high quality water. However, the presence of Owena multipurpose dam reduced the water-stress condition of Ondo-West, Ondo- East and Akure South local government. In addition, Awara dam serves Akoko N-E and some part of Akoko N-W, while Ose dam serves Owo and Ose local government areas as presented in Table 3. Aquifer in this region discharges sufficient amount of water which improves the yield of an average borehole in the above-named local government areas. Most of the faulty boreholes happened as a result of mishandling by dwellers, minor electrical and mechanical problems which could be easily corrected by community project management team.

Table 1: WPI and IWMT values for all the local government areas in Ondo-State in wet season.

S/N	L.G.A	T_T (min)	T_v (liters)	WPI	IWMT
1.	Akoko N-E	110	200	0.55	1.0
2.	Akoko N-W	130	200	0.65	1.2
3.	Akoko S-E	140	200	0.70	1.3
4.	Akoko S-W	110	200	0.55	1.0
5.	Akure-North	102	200	0.51	0.9
6.	Akure-South	105	200	0.53	1.0
7.	Ese-Odo	240	200	1.20	2.2
8.	Ifedore	130	200	0.65	1.2
9	Ifelodun	130	200	0.65	1.2
10.	Ilaje	226	200	1.13	2.1
11.	Ileoluji/Okegbo	130	200	0.65	1.2
12.	Irele	200	200	1.00	1.9
13.	Odigbo	180	200	0.90	1.7
14.	Okitipupa	150	200	0.75	1.4
15.	Ondo-East	125	200	0.63	1.2
16	Ondo-West	89	200	0.44	0.8
17	Ose	90	200	0.45	0.8
18.	Owo	100	200	0.50	0.9

Source: Field data,2011

Table 2 : WPI and IWMT values for all the local government areas in Ondo-State in dry season.

S/N	L.G.A	T_T (min)	T_v (liters)	WPI	IWMT
1.	Akoko N-E	120	200	0.60	1.1
2.	Akoko N-W	140	200	0.70	1.3
3.	Akoko S-E	135	200	0.68	1.3
4.	Akoko S-W	130	200	0.65	1.2
5.	Akure-North	130	200	0.65	1.2
6.	Akure-South	120	200	0.60	1.1
7.	Ese-Odo	273	200	1.40	2.6
8.	Ifedore	152	200	0.76	1.4
9	Ifelodun	150	200	0.75	1.4
10.	Ilaje	240	200	1.20	2.2
11.	Ileoluji/Okegbo	152	200	0.76	1.4
12.	Irele	216	200	1.08	2.0
13.	Odigbo	190	200	0.95	1.8
14.	Okitipupa	165	200	0.83	1.5
15.	Ondo-East	145	200	0.73	1.4
16	Ondo-West	106	200	0.53	1.0
17.	Ose	100	200	0.50	0.9
18.	Owo	110	200	0.55	1.0

Source: Field data,2011

Table 3: Source of functional safe drinking water in Ondo-State

S/N	L.G.A	No of solar-powered Boreholes	No of hand pump Boreholes	No of modern grouted wells	No of dams
1.	Akoko N-E	8	32	24	1
2.	Akoko N-W	9	26	22	-
3.	Akoko S-E	7	23	20	-
4.	Akoko S-W	10	33	25	-
5.	Akure-North	12	37	44	-
6.	Akure-South	10	30	40	-
7.	Ese-Odo	4	14	9	-
8.	Ifedore	8	23	21	-
9.	Ifelodun	10	20	20	-
10.	Ilaje	5	20	14	-
11.	Ileoluji/Okegbo	9	24	21	-
12.	Irele	6	22	17	-
13.	Odigbo	7	23	21	-
14.	Okitipupa	8	22	23	-
15.	Ondo-East	9	30	23	-
16.	Ondo-West	10	35	28	1
17.	Ose	11	32	27	1
18.	Owo	12	34	30	-

Source: Field data, 2011

Water from pond, stream, river, sea and traditional well is generally considered unsafe for drinking. Due to the presence of abundant salty seawater at Ese-Odo, Irele and Odigbo local government areas, development of surface and underground water becomes a problem. Despite the huge financial resource expended on provision of portable water at Ese-Odo and Irele local government areas, majority of the boreholes were not functioning and most of the functional ones are not very good for drinking as shown in Table 6. Finding also reveals that seepage of salty seawater into boreholes has contaminated most of the boreholes in the region

and becomes highly unsafe for drinking. Thus, in turn make the development of underground water to be highly difficult and expensive. Converting seawater to safe drinking water either by desalination or any other processes has not been developed in this part of the world and this makes the exploitation of surface water impossible.

b) Computation of IWMT and WPI using Adjusted Composite Index approach

Tables 4 and 5 show the computed WPI values for wet and dry season using composite index approach.

Table 4: WPI and IWMT values for all local government areas in Ondo-State during wet season

S/N	L.G.A	Water Availability (%) Weight: 0.5	Access to Water (%) Weight:0.25	T _{Index}	Index to time spent (100-T) Weight:0.25	WPI	IWMT
1.	Akoko N-E	59.6	56.1	30.0	70.0	15.9	22.1
2.	Akoko N-W	28.7	53.2	35.0	65.0	14.6	20.3
3.	Akoko S-E	40.3	51.0	50.2	49.8	15.0	20.9
4.	Akoko S-W	45.9	49.8	56.1	43.9	15.5	21.5
5.	Akure-North	50.1	58.1	29.3	70.7	19.1	26.5
6.	Akure-South	57.8	63.2	28.6	71.4	20.9	29.1
7.	Ese-Odo	74.6	6.0	93.6	6.4	13.5	18.8
8.	Ifedore	33.2	50.1	49.9	50.1	13.9	19.3
9.	Ifelodun	40.4	49.3	57.3	42.7	14.4	20.0
10.	Ilaje	71.8	10.0	91.6	8.4	13.5	18.8
11.	Ileoluji/Okegbo	60.2	39.8	75.0	25.0	15.4	21.4
12.	Irele	68.2	14.0	86.7	13.3	13.6	18.9
13.	Odigbo	67.9	16.0	80.1	19.9	14.3	19.9

14.	Okitipupa	65.5	18.0	75.3	24.7	14.5	20.2
15.	Ondo-East	43.4	55.2	36.7	63.3	17.1	23.8
16.	Ondo-West	59.6	60.3	29.0	71.0	20.9	29.1
17.	Ose	50.2	68.3	25.0	75.0	20.3	28.2
18.	Owo	48.1	55.1	26.2	73.8	19.6	27.2

Source: Field data, 2011

Table 5 : WPI and IWMT values for all local government areas in Ondo-State during dry season

S/ N	L.G.A	Water Availability (%) Weight: 0.5	Access to Water (%) Weight:0.25	T _{Index}	Index to time spent (100-T) Weight:0.25	WPI	IWMT
1.	Akoko N-E	30.3	52.1	40.5	59.5	14.4	20.0
2.	Akoko N-W	25.1	49.6	46.9	53.1	12.7	17.7
3.	Akoko S-E	24.0	49.8	46.4	53.6	12.6	17.5
4.	Akoko S-W	22.6	42.3	50.1	49.9	14.5	20.2
5.	Akure-North	41.6	50.1	44.6	55.4	15.7	21.8
6.	Akure-South	32.6	60.0	35.4	64.6	15.8	21.9
7.	Ese-Odo	55.1	5.3	94.6	5.4	10.1	14.0
8.	Ifedore	29.6	48.2	48.9	51.1	13.2	18.3
9.	Ifelodun	26.1	40.3	56.7	43.3	11.3	15.7
10.	Ilaje	50.3	10.2	82.4	17.6	10.7	16.3
11.	Ileoluji/Okegbo	45.6	33.2	65.9	34.1	13.2	18.3
12.	Irele	49.3	20.8	78.6	21.4	11.7	16.3
13.	Odigbo	37.2	30.6	68.9	31.1	11.3	15.7
14.	Okitipupa	45.3	30.1	69.6	30.4	12.6	17.5
15.	Ondo-East	40.3	51.6	42.0	58.0	15.9	22.1
16.	Ondo-West	40.1	53.2	39.6	60.4	16.2	22.5
17.	Ose	40.1	60.2	35.2	64.8	17.1	23.8
18.	Owo	42.1	62.1	32.4	67.6	17.8	24.7

Source : Field data, 2011

The comparison of WPI and IWMT in Table 4 and 5 showed that Akure-South and Ondo-West local government areas recorded highest WPI and IWMT values of 20.9 and 29.1 (index point) during the wet season. This indicator shows that the two local government areas experienced lowest degree of water stress. Ese-Odo and Ilaje local government areas recorded the lowest WPI and IWMT value of 13.5 and 18.8 (index point) each. The regions are heavily water-stressed. The values of WPI and IWMT obtained during the drying season period showed that Owo local government area has the highest value of 17.8 and 24.7 (index point), while Ese-Odo local government recorded development showed that Ese-Odo local government and its environs are strongly water-stressed at both dry and wet seasons, while Ondo-West, Ose, Owo, Akoko N-E, Akoko N-W, Akoko S-W, Akoko-South and Akure North are generally less water-stressed with fair access to safe drinking water at all season. The population of people that have no or poor access to safe drinking water was estimated for two concurrent years and the result in Table 6 showed that Ese-Odo was ranked to be the highest with 94.7% and 89.2%, while lowest values of 37.9% and 35.9% for the year 2007 and 2008

respectively. This also explains further the degree of water stress status at Ese-Odo local government area despite the financial commitment on the provision of portable water between year 2007 and 2008 by government at every level and some donor agencies. However, fairly accessibility of portable water at Owo local government area and its environs is not enough to satisfy the water demand of the dwellers and so more technical and financial commitment must be invested to improve the volume of safe drinking water and the percentage of dwellers that can access it. Analysed data in Table 9 showed that the percentage of people that had no access to freshwater reduced from 58.4% (2,613,584) to 54.8% (2,452,472) between the year 2007 and 2008 respectively. The reduction is strongly correlated to the investment in water and sanitation within the period of assessment.

Table 6 : Ranking of Investment in Water and Sanitation in all the local government areas in Ondo-State

S/N	L.G.A	Investment (₦)	2007	Investment(₦)	2008
1.	Akoko N-E	80,333,245.16	8	89,769,240.23	9
2.	Akoko N-W	70,900,345.96	11	77,780,236.19	12
3.	Akoko S-E	63,567,176.00	15	65,467,105.19	18
4.	Akoko S-W	78,670,200.17	9	86,450,789.16	10
5.	Akure-North	88,540,070.33	7	99,765,129.26	8
6.	Akure-South	89,205,100.56	5	102,134,256.18	6
7.	Ese-Odo	90,105,255.13	4	105,452,245.10	4
8.	Ifedore	70,000,200.45	12	73,265,105.99	14
9	Ifelodun	68,900,245.12	14	73,451,243.86	13
10.	Ilaje	89,205,070.12	6	106,126,243.23	3
11.	Ileoluji/Okegbo	69,540,100.13	13	78,900,733.45	11
12.	Irele	59,240,100.43	17	70,106,345.67	15
13.	Odigbo	59,470,214.12	18	67,780,567.88	17
14.	Okitipupa	60,120,473.10	16	68,450,453.12	16
15.	Ondo-East	75,245,250.77	10	100,500,345.18	7
16	Ondo-West	98,000,582.22	1	124,578,217.24	1
17.	Ose	95,325,420.19	2	108,432,106.13	2
18.	Owo	93,216,110.10	3	103,221,103.25	5

Source: Data from the survey

Table 7 : Ranking of population without access to safe water in all the local government areas in Ondo State

S/N	L.G.A	Population (%) (2007)	Population (%) (2008)	Ranking
1.	Akoko N-E	47.9	43.2	14
2.	Akoko N-W	50.4	47.3	10
3.	Akoko S-E	50.2	49.6	11
4.	Akoko S-W	57.7	53.3	8
5.	Akure-North	49.9	45.9	12
6.	Akure-South	40.0	36.3	16
7.	Ese-Odo	94.7	89.2	1
8.	Ifedore	51.8	49.1	9
9	Ifelodun	59.7	55.3	7
10.	Ilaje	89.8	84.7	2
11.	Ileoluji/Okegbo	66.8	66.2	6
12.	Irele	79.2	75.2	3
13.	Odigbo	69.4	65.1	5
14.	Okitipupa	69.9	65.3	4
15.	Ondo-East	48.4	40.8	13
16	Ondo-West	46.8	46.9	15
17.	Ose	39.8	36.2	17
18.	Owo	37.9	35.9	18

Source: Data from the survey, 2011

Table 8 : Estimated average total population without access to safe water in all the local government areas in Ondo-State

Year	Average total population (%)	Estimated population
2007	58.4	2,613,584.
2008	54.8	2,452,472

IV. CONCLUSIONS

The study evaluated Integrated Water Management Tools (SWPI) and compared the results with Structural Water Poverty Index (SWPI). The results obtained from the two approaches indicated that Ese-

Odo, Ilaje and Irele local government areas are the most water-stressed, while areas such as Ose, Owo, Ondo-West, and Ondo-East local government areas have fair access to portable water. Heuristic application of Integrated Water Management Tools (IWMT) to test the

generated dataset provided flexible and strong decision-making strategies in such a way as to construct a holistic water management tool to address the problems of scarcity, and its relation to water access and use. SWPI, cannot link complex multidimensional aspects of water management together as a result of this, IWMT approach is always preferable. The results presented various approaches to test our standardized data sets are expected to enhance our understanding of the significant effects of water poverty to economy, human development, health and education. Many states and local government areas are moving towards a point where water resources are insufficient for agriculture, drinking and other domestic uses and to prevent the occurrence of *virtual water*, further researches are needed to be conducted regularly on water problems and proffer realistic and technical solution to enhance the supply of safe drinking water at reasonable distance in all strategic locations across communities and regions in developing countries.

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GLOBAL JOURNAL OF SCIENCE FRONTIER RESEARCH
AGRICULTURE AND VETERINARY SCIENCES

Volume 12 Issue 7 Version 1.0 Year 2012

Type : Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals Inc. (USA)

Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Dyeing of Cotton / Nylon Blended Fabric to a Solid Shade in One Bath

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Abstract - Cotton / Nylon blended fabrics are normally dyed by two-bath or one-bath two-step dyeing method. This paper deals with dyeing nylon/cotton blends to a solid shade in one bath using one dye. In this study, the fabric treated with chloroacetic acid (CAA), to form the anionic form followed by the cationization form using the inorganic salt of magnesium chloride. The effect of treatments on dyeability, fastness, and few physicochemical properties has been investigated, and results are presented. The dyed fabric featured excellent tone-in-tone effects and color fastness, and the process featured shortened time and saved cost.

Keywords : *Egyptian cottons, Nylon, Modification treatment, Dyeing, Cationization, and Fabric blend.*

GJSFR-D Classification : *FOR Code: 860406*



Strictly as per the compliance and regulations of :



Dyeing of Cotton / Nylon Blended Fabric to a Solid Shade in One Bath

Salah. M. Saleh ^α & K. El-Badry ^σ

Abstract - Cotton / Nylon blended fabrics are normally dyed by two-bath or one-bath two-step dyeing method. This paper deals with dyeing nylon/cotton blends to a solid shade in one bath using one dye. In this study, the fabric treated with chloroacetic acid (CAA), to form the anionic form followed by the cationization form using the inorganic salt of magnesium chloride. The effect of treatments on dyeability, fastness, and few physicochemical properties has been investigated, and results are presented. The dyed fabric featured excellent tone-in-tone effects and color fastness, and the process featured shortened time and saved cost.

Keywords : Egyptian cottons, Nylon, Modification treatment, Dyeing, Cationization, and Fabric blend.

1. INTRODUCTION

Egypt is the largest producer in Africa and worldwide of long (LS) and extra long staple (ELS) cotton, accounting for 50 percent of world production in 2009, it has built a brand reputation for its quality of cotton, 2010.

Blending is a complicated and expensive process, but it makes it possible to build in a combination of properties that are permanent, Gupta et al. 2007. Not only are blend used for better serviceability of fabrics but they are also used for improved appearance and hand. Blends of synthetic fibres with natural fibres offer the most valuable possibilities for combining desirable physical properties, because the two components are so dissimilar. Different fibres can be blended in textile structures to obtain the desirable properties of each of the fibres in the blend.

A blended yarn or fabric generally displays an averaging of the properties of the constituent fibres. When properly combined with cotton, nylon adds strength, which allows the development of unusually fine 'textures' and nylon provides smoothness, silkiness, and dirt rejection. It also reduces the weight of the fabric and increases its wrinkle resistance. The cotton gives softness and moisture absorption. If the combination is not properly balanced, the cotton may shrink, causing the fabric to pucker. Also the nylon fibers may cut the cotton fibers. A blend of at least 17% high-tenacity nylon staple with cotton can make a very durable fabric, Bloom, 2011.

Tactel (TCI) Nylon/Cotton blends have been strongly promoted in sports wear. Good solidity of hue

and depth is more critical in 50:50 blends and in union fabrics, such as nylon warp stretch fabrics, containing cotton or nylon/ cotton wefts for swim wear and narrow fabrics, crimped nylon warp/viscose filament dress wear, or cotton warp/nylon weft constructions for uniforms, rain wear or work wear. Nylon/cotton is also used in socks.

There are various possibilities regarding the choice of dye classes for solid effects on nylon/cellulosic blends. Direct, acid, and reactive dyes are the most widely used anionic dyes for cotton, Koushic & Sonia, 2010.

Cellulose fibers when immersed in water produce a negative zeta potential and most of the dye classes suitable for cotton are anionic in nature. The negative charge on the fiber repels the anionic dye ions and consequently the exhaustion of the dye bath is limited. However this zeta potential can be easily offset by salt concentrations of about 10.000 – 100.000 ppm which cause environmental problems. But in the absence of these electrolytes a large part of the dye remains unexhausted and gets discharged in the effluent stream. To overcome these problems cationization of cotton has been studied by Chavan et al, 1998. Cationization of cotton is emerging as an effective tool that solves the environmental problems associated with dyeing of cotton with anionic dye, Subramanian et al. 2006.

Nylon being a polyamide contains many amide groups in its structure. It also contains free amine groups at the ends of its polymeric chains, although the number of these free amine groups is less than the number of carboxylic groups, and therefore, the fiber possesses a negative charge unless in the appropriate pH region. These amide and amine groups provide excellent hydrogen bonding sites and are the main factors contributing to the substantivity of the dye molecules, Baig, 2010.

Apart from fastness considerations, the choice of dye system is much influenced by blend construction. Single-class methods are mainly used where the nylon is minor component, the nylon occupying the interior or the reverse side of the construction. Reserve, shadow and limited contrast effects are practicable on nylon/cellulosic blends, but seldom encountered in practice. Most acid dyes have very little affinity for cotton, but cationic cotton can be dyed readily with acid dyes. The ammonium groups act as dye sites.

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Therefore, with blended fabrics or mixed fabrics, using cationic cellulosic fiber and regular cotton, two-tone effects can be obtained in one-bath dyeing. Meanwhile, this phenomenon gives a possibility to one-bath dyeing for blended fabrics, using cationic cellulosic fiber and nylon, Draper et al. 2003.

Dyeability of cationized cotton and a nylon 6 fabric using acid dyes was described by Badawy et al. 2011. One-bath dyeing of cotton-nylon mixture with reactive and acid dyes was mentioned by Shang Runling. Anionic dyes such as direct, reactive, acid and solubilized sulfur dyes are attracted by the cationic charges imparted to the fabric by the cationic agent. Bright hues with excellent fastness can be achieved on nylon/cellulosic blends using reactive dyes. Some control over the distribution between nylon and cellulose is possible by selection of dyebath pH, temperature and electrolyte concentration.

Nylon is favored at low applied depths but the distribution shifts in favor of the cellulosic fiber as the saturation level of nylon is approached. The facility to attain high wet fastness standards on nylon/cellulosic blends by a one-bath technique at mildly acidic pH is a substantial advantage over the two-bath or two-stage

procedures based on reactive dyes, Hook & Welham, 1988.

The main objective of this research is the ability to dye cotton/nylon blends in one step, one dyeing bath after the treatment of the fabric with the anionic chloroacetic acid followed by the cationization of the fabric with magnesium chloride. The process featured shortened time and saved cost.

II. MATERIALS AND METHODS

The fiber properties of long staple Egyptian cotton variety Giza 86 selected to blend with nylon 6,6. Giza 86 was measured in Cotton Research Institute (CRI) labs by HVI spectrum instrument, The Cotton Research Institute Quality Test Corp 2010. The cotton samples were spun to 20s, with twist multiplier "4.0 T.M. using the olfil RST machine, this spinning technique was carried out according to the conventional method used at the experimental spinning mill. All of those yarns produced under controlled atmospheric conditions of $20^{\circ}\text{C} \pm 2$ temperature and $65\% \pm 2\%$ Relative humidity. The produced yarn properties of Giza 86 and nylon 6,6 materials were shown in Table1.

Table1 : The produced yarn properties of Giza 86 and nylon 6, 6

Yarn properties of Giza 86	Yarn properties of nylon 6, 6
Thick places1	linear density 940 dtex
Thin places 0	Number of filaments 140
Neps 1	Breaking force 79.5 N
Elongation % 7.41	Breaking tenacity 844 mN/tex
C.V % 11.57	Elongation at break 17.9 %
Tenacity 20.22	Elongation at specified force9.6 %
-----	Hot air shrinkage 3 min. at 80°C were 5.1 %

a) Production of Cotton/ Nylon knitted fabric

Yarn samples were suitably waxed and identically knitted into single jersey fabric with the same construction on a flat knitting machine, half jacquard dyamant machine Model 1987 from Italy. Goge 10 with 10 needles per inch and width is 100 cm. This was followed by Cairo Secondary School for spinning and weaving. Cotton and nylon yarns were blended in the carding stage with knitting flat machine as 5 different ratios as follows: 100% cotton, cotton / nylon 75 :25 %, cotton / nylon 50 :50 %, cotton / nylon 25:75 % and 100 % nylon.

b) Chemicals

All of chemicals used were of analytical grade and used without purification.

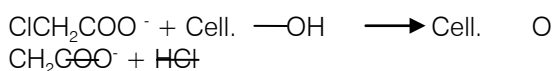
c) Treatment processes

Scouring and bleaching of cotton/nylon blend

The blended samples were scoured and bleached according to the process obtained by Karmakar, S. R (1999).

d) Treatment of blended cotton-nylon with chloroacetic acid(CAA)

Treatments of the blended samples with CAA were carried out as shown in the following equation according to Hashem et al. 2003.



The carboxylic acid group content of the partially carboxymethylated cellulosic fabrics were determined according to the method described by J. William 1984, and It was found that the carboxylic contents were 114.54.

e) Cationization of blended cotton-nylon with magnesium chloride

Blended fabrics were treated by magnesium chloride as shown in Figure 1, using pad dry cure procedure. The solutions were prepared as follows 40.6g (0.2 mole) from magnesium chloride hexahydrate

dissolved in 400 ml of deionized water. It yielded to 0.5M of aqueous $MgCl_2$ solution. The pad dry cure application method was applied and followed by washing and drying according to Mustafa Bilgin, 2005.

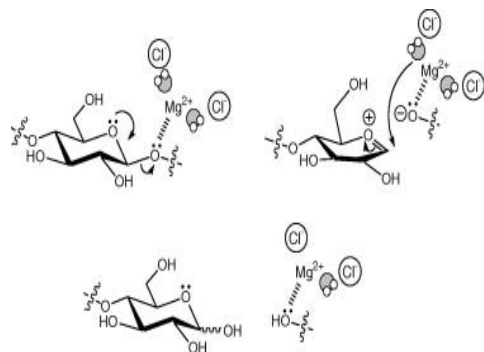


Figure 1 : Cationization of the treated fabric with $MgCl_2$

f) Dyeing process

Dyeing of the pretreated union fabrics were carried out in the laboratory dyeing machine by the pad method. The unmodified and modified fabrics were dyed with (4% owf) Acid red C.I. 108 as shown in Figure.2 in a bath containing (8%owf) Amonium acetate and (4% owf) hydrochloric acid 30%, with with a liquor ratio of 1:20.

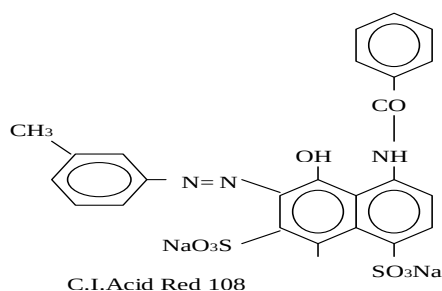


Figure 2 : Chemical structure of C. I Acid Red 108

Firstly, salt and acid were added to water and the dyeing bath was warmed at 50° C, then the samples were immersed in the dyeing bath and the dyeing continued for 10 min., followed by adding the dye solution and the dyeing continued for 15 min., then the temperature was raised to boiling through 20 min, the dyeing was continued at this temperature for (45 min). finally the dyeing was stopped and the dyeing bath was cooled. Dyed samples were thoroughly rinsed with running cold water, then soaped with a solution containing 5g/l nonionic detergent (Hostapal CV-ET) and 1g/l Na_2CO_3 at 40°C for 15 min, Soaping were carried out for 4 times to ensure good washing fastness. Finally rinsing with hot and cold water after wash the samples were left air dried.

III. MEASUREMENTS

a) Dyeability measurements

The color strength (K/S) of the treated samples using the untreated samples as blank was determined using perkin Elmer spectrophotometer, Model Lambda35 equipped with integrated sphere according to Kubelka- Munk equation].

$$K/S = (1-R)^2 / 2R$$

Where:-

R: Decimal fraction of the reflectance of dyed samples.

K: Absorption coefficient.

S: scattering coefficient

The color components L^* , a^* , and b^* were measured according to CIE L^* , a^* , b^* . ASTM E 308-96, computing the colors of object by using the CIE system.

Total color difference (ΔE), hue (h) and chroma (c) were computed by spectrophotometrical determine by using the following equations:

$$\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$$

$$C_1^* = \sqrt{a_1^{*2} + b_1^{*2}}$$

$$h_{ab} = C. \tan b / a$$

Where (L_1^* , b_1^* , a_1^*) of reference color , (L_2^* , b_2^* , a_2^*) of target color.

b) Estimation of bursting strength

The bursting strength of the knitted fabrics were determined by the standard method ASTM D 3787- 07, Air permeability was determined by the standard procedure ASTM D737-04 (2008), thickness was determined by the standard procedure ASTM D 1777-96 (2007), and the Abrasion was determined by the standard procedure Martindale ASTM D 4157- 10.

c) Fastness properties

Washing fastness of the dyed samples was done according to the AATCC test method 16-1972. Fastness to synthetic perspiration was measured according to ISO-E04: 1994. Fastness of light was measured according to the ISO 105:1997 using standard wool gray scale as reference in all testes.

IV. RESULTS AND DISCUSSIONS

a) Color measurements of the cotton/nylon blends

It has been observed that the color measurements have the lowest values of cotton as shown in table 2. This was because cotton fibers when immersed in water produce a negative zeta potential

and most of the dye classes suitable for cotton are anionic in nature. The negative charge on the fiber repels the C. I Red 81 dye ions and consequently the exhaustion of the dye bath is limited which leads to the decrease of the color measurements. Also, as the CAA treatment increases the negative charge on cotton, the color measurement decreases. On the other hand, the color measurements of nylon were limited due to the competition of CAA and C. I Red 108 dye ions to react with the positive charge of amide group of nylon. The large differences between the color measurements of the nylon/cotton knitted fabrics may also arise from the differences of the molecular structure of the fibers. It is well known that the diffusion of dye molecules into fibers mainly depends on the size and distribution of the crystalline (ordered) and amorphous (disordered) regions. The color measurements of cotton/nylon blends increased with the cationization with magnesium chloride. Magnesium chloride reacts

with the negative charges present on cotton/nylon blend surface. The C. I Red 108 anionic ions react with the positive charges of the blends and the color measurements increased. The variation of the color measurements of the different blend ratios was due to the ability of the anionic dyes to react with the positive charges present due to the surface area and the number of pores present. It has been pointed out that the highest chroma (measures color saturation) values indicate that the cotton/nylon 75:25% fabrics are dyed with the highest saturation and the colors obtained are the brightest. The values of the hue angle (runs between 0° and 360° measures color range and the angles of 0°, 90°, 180°, 270° refers to red, yellow, green, and blue shades respectively) showed that all the samples were closer to red color. The highest h values of the cotton/nylon 75:25% fabrics indicate that these fabrics have the reddest appearance.

Table 2 : Color measurements of the cotton/nylon blends dyed

Samples	K/S	L	a	b	ΔE	C	h
Cotton 100%	4.22*	44.9	23.5	1.9	50.7	23.5	4.6
	7.27**	39.9	27.6	3.75	48.1	27.8	7.7
Cotton/ nylon 25:75%	7.90	37.2	32.5	2.3	49.4	32.6	5.6
	8.20	34.9	26.8	5.8	53.5	27.4	12.2
cotton /nylon 75:25%	4.52	34.3	24.5	1.7	42.1	24.5	3.9
	5.95	39.1	29.8	4.8	49.4	30.1	9.1
cotton /nylon 50:50%	5.70	43.1	21.1	3.7	48.1	21.4	20.1
	6.20	50.6	20.5	3.64	54.6	20.8	10
Nylon 100%	4.30	37.77	26.20	1.8	52.9	25.3	3.2
	6.30	39.47	24.20	3.8	49.9	28.3	6.2

*Treatment of the blend with CAA ** Treatment of the blend with $MgCl_2$

Dyeing bath: Acid red C.I 108 (4%), temp: 50°C, time: 90 min, L.R. 1:50

b) Mechanical properties of cotton/nylon blends

The results obtained in Table 3 revealed that the bursting strength of cotton 100% and nylon 100% decreased after the cationization treatment. Bursting strength increased with the increase of the nylon percent in the blend. The highest values for the treated sample Cotton/ nylon 25:75% is 614. Blends containing less than 50% nylon were actually weaker than all-cotton yarns. Owing to the lower modulus of the nylon,

the load on the yarn as it was extended was increasingly borne by the cotton fibers in the blend. This was due to the bleaching nylon/cotton blends with hydrogen peroxide at the boil. The amount of peroxide affects the proportion of nylon present and an oxidative damage of the nylon occurred lowering the bursting strength of the blends. A greater relative increase in air permeability was observed with increasing synthetic fiber content. It was concluded that air permeability of

cotton /nylon 25:75% fabrics was found to be higher by about 20-25% than other blends. The cotton/nylon blended fabrics also exhibited higher air permeability values as compared to cotton fabrics. It also pointed

out that nylon reduces the weight of the fabric and increases its air permeability. The abrasion resistance of nylon 6, 6 was higher than cotton. The abrasion resistance increase as the nylon ratio increased in the blend.

Table 3 : Mechanical properties of cotton/nylon blends

Samples	Bursting Strength kg/cm ²	Thickness mm	Air permeability cm ³ /cm ² /sec	Abrasion resistance
100%cotton	530.00*	1.6	57	220
	468.00**	1.5	61	117
25%cotton:75%nylon	616.00	1.1	88.3	288
	688.00	1.0	100.3	397
75%cotton:25%nylon	409.00	1.4	67.3	154
	514.00	1.3	80.3	258
50%cotton:50%nylon	493.00	1.25	84.7	207
	663.00	1.2	91.3	356
100%nylon	1000.00	0.91	149.3	455
	892	0.96	122.1	412

*Treatment of the blend with CAA ** Treatment of the blend with $MgCl_2$

c) Fastness properties of cotton/nylon blends

It can be seen from Table 4 that the wash fastness gave the similar ratings between 3/4 and 4/5. The staining tendency on the adjacent fabrics is much less, the fastness showed such good performance that it may be due to the mineral matter present on the cotton fabric. The metal salts which might be forming chelates with the dyes inside the substrates. Acidic and alkaline samples show good -very good (3/4- 4/5) with respect to color change, however, staining of the adjacent fabric is to some extent high of dyed samples. It can be seen that the light fastness ratings between (3/4 -6) with respect to color change, however, staining of the adjacent fabric is to some extent high of dyed samples.

As in the case of the wash fastness results, no shade changes are observed for the all fabrics after the perspiration fastness tests. In terms of staining, the acidic perspiration fastness results of all the fabrics are better than the alkali perspiration results. Fiber type seems to have no significant effect on the acidic perspiration results. The light fastness results of all the fabrics are good. The highest light fastness result of the cotton/nylon fabrics may be attributed to the natural UV resistant property of nylon fibers as stated previously in the study of Sheshachala et al.2008. In general, deeper

and darker colors usually lead to an increase in the light fastness results of fabrics. Therefore, the deepest and darkest colors of the nylon/cotton fabrics, due to the highest K/S and the lowest L* values, may also be the other reason for the highest light fastness results of these fabrics.

Table 4 : Fastness properties of cotton/nylon blends

Samples	Washing fastness 40°C		Perspiration fastness				Light fastness
			Acidic		Alkaline		
	Gray	Stain	Gray	Stain	Gray	Stain	
100%cotton	3/4	4/5	3/4	4	4	4	3/4
	4/5	4	4	4/5	4	4	4/5
25%cotton:75%nylon	5	4/5	5	5	5	5	5
	5	4/5	4/5	4	4/5	4	4
75%cotton:25%nylon	4/5	4/5	4/5	4	4/5	4/5	4/5
	3/4	4/5	3/4	3/4	3/4	4	3/4
50%cotton:50%nylon	4/5	4/5	4/5	4	4	4/5	4/5
	4/5	5	4/5	4	4	4	4/5
100%nylon	5	5	5	5	5	5	6
	5	5	5	5	5	5	6

*Treatment of the blend with CAA ** Treatment of the blend with $MgCl_2$

V. CONCLUSIONS

This research described the ability to dye cotton/nylon blends in one step, one dyeing bath after the treatment of the fabric with the anionic chloroacetic acid followed by the cationization of the fabric with magnesium chloride. The results obtained revealed that the cotton/nylon 75:25% have the highest color measurement values, highest color fastness, while cotton/nylon 25:75% represented the highest air permeability, and the highest abrasion resistance. The process featured shortened time and saved cost.

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GLOBAL JOURNAL OF SCIENCE FRONTIER RESEARCH
AGRICULTURE AND VETERINARY SCIENCES

Volume 12 Issue 7 Version 1.0 Year 2012

Type : Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals Inc. (USA)

Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Growth and Yield Response of Okra (*Abelmoschus esculentus* (L.) Moench) Varieties to Weed Interference in South-Eastern Nigeria

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Keywords : Okra varieties, South-eastern Nigeria, weed interference, weed control efficiency, fruit yield.

GJSFR-D Classification : FOR Code: 070308



Strictly as per the compliance and regulations of :



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Iyagba A.G.^a, Onuegbu^σ, B.A & IBE, A.E.^p

Abstract - Field Studies were conducted at the Federal University of Technology, Owerri, Nigeria to determine the influence of weed interference on the growth and yield of three okra (*Abelmoschus esculentus* (L.) Moench) varieties. Three varieties of okra (NHAe47-4, Lady's finger and V₃₅) were weeded using five weeding regimes (weedy check, unweeded till 5 weeks after sowing (WAS), weeding once each at 3 WAS and 4 WAS and weed free). The treatment combinations were laid out in a randomized complete block design with three replications. Plant height for okra varieties was in the decreasing order of Lady's finger < NHAe47-4 < V₃₅ while leaf area was in the increasing order of NHAe47-4 > V₃₅ > lady's finger in both years. More flowers/plant were obtained from NHAe47-4 while the least number of flowers aborted were obtained from the Lady's finger. Among the weeded plots, NHAe47-4 produced the highest fresh fruit yield (23.63t ha⁻¹ in 2007 and 22.96t ha⁻¹ in 2008) which were not insignificantly different from the yields obtained from weed free plots that produced 24.20t ha⁻¹ in 2007 and 22.13t ha⁻¹ in 2008. Better weed control was obtained from NHAe47-4, 80.63% in 2007 and 76.97% in 2008 comparable with the weed free plots. From this result it can be concluded that okra variety NHAe47-4 weeded at 3 WAS seems more appropriate in this zone.

Keywords : Okra varieties, South-eastern Nigeria, weed interference, weed control efficiency, fruit yield.

I. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the most important vegetables grown in the tropics. In Nigeria it is produced predominantly by peasant farmers usually in home gardens or in mixture with other cereal crops (Lombin *et al.*, 1988). It is grown for its young leaves and green pods. Okra seeds contain about 20% protein similar to amino acid composition of soybean protein and 20% oil (similar in fatty acid composition to cotton seed oil) (Siemonsma and Hamon, 2002). Okra flowers can be very attractive and sometimes used in decorating the living rooms (Schippers, 2000). The fruits are exported by some

African and Caribbean countries to Europe and America where there is a ready demand from the resident ethnic groups from tropical and sub-tropical countries including Indians, West Africans, Pakistanis and Surinamese (Adetula and Denton, 2003). The world production of okra as fresh fruit vegetable is estimated at 6 million t ha⁻¹. In Nigeria, the limiting factors in okra production and other vegetables among others include weed management, tillage practices, low yielding varieties and sub-optimal planting density (Adejonwo *et al.* 1989; Burnside, 1993; Dikwahal *et al.* 2006, Adeyemi *et al.*, 2008). Whether grown as a sole crop or intercrop, the problem of weed interference still persists. Excessive weed growth is one of the most serious factors affecting the performance of crops generally and vegetables in particular. Such effects may be direct or indirect and the degree of competition encountered by an individual crop depends among others on the spacing, fertility of the soil, species of weeds associated as well as other climatic factors. Substantial evidence has shown that when weeds interfere with vegetables like okra it affects their vegetative and reproductive growth. The time of weed removal is therefore as important as the removal itself.

William and Warren (1975) recorded 63% crop loss in okra as a result of weed competition in Brazil while Singh *et al.* (1981) observed 76.5% loss in okra seed yield in unweeded plots. In Nigeria Adejonwo *et al.* (1989) reported that uncontrolled weed growth throughout the crop life cycle reduced okra fruit yield between 88 and 90% compared with those kept weed free throughout the growth period. It has also been noted that the critical period of weed competition in okra occurred between 3 and 7 weeks after sowing (William and Warren, 1975). Adejonwo *et al.* (1989) reported that keeping the crop weed free until 3 weeks after sowing (WAS) depressed growth and yield of okra due to the adverse effect of subsequent weed infestation while weed infestation until 3 WAS and thereafter keeping the plots weed-free had no adverse effect on okra plants. Okra varieties are sensitive to environmental changes (Thamburaj, 1982; Grubben, 1999; Ezeakume, 2004; Katung, 2007; Ijoyah *et al.*, 2009). Ijoyah *et al.* 2009, noted that NHAe47-4 provided a better yield during the

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wet season than in the dry season, whereas differences in yield were not significantly different in the wet and dry season with variety 'Ex – Ajia'. The use of crop variety is a means of reducing pest attack in okra production invariably leading to higher yield. Alegbejo (2003) observed that out of 15 okra varieties screened for resistance to okra mosaic virus genus Tymovirus (OMV) in Samaru, Nigeria, 2 cultivars NHAe47-4 and DA97/408 were moderately resistant while the other 13 were highly susceptible. The use of resistant varieties is an alternative to chemical pest control which is not readily available to the peasant okra farmers and also means of reducing environmental pollution. The performance of a crop depends on an interplay of its genetic constitution, the environment under which it is grown and management practices adopted in the culture. The three okra varieties commonly cultivated in the South-Eastern Nigeria are NHAe 47-4, V₃₅ and Lady's finger. The extent of crop loss to weed interference by these varieties may differ. This study was therefore carried out to determine the response of these okra varieties to various periods of weed interference.

II. MATERIALS AND METHOD

Two field studies were conducted at the Federal University of Technology Teaching and Research Farm, Owerri, Nigeria situated between Latitudes 5°20'N and 5°27'N and between Longitudes 7°E and 7°07'E in May, 2007 and 2008. The area has a bimodal rainfall with annual mean rainfall of 240 and 137mm in 2007 and 2008 respectively. There are two seasons: the wet season from April to October and dry season from November to March with a characteristic cold dry dust laden wind interval (harmattan) during the months of January through February.

Soil sample was collected before the planting, oven-dried, ground and sieved through 2mm sieve and the sand, silt and clay contents were determined by the Bouyoucos method (1951). The soil pH was determined using the pH-metre in a 1:2.5 soil/water ratio, total nitrogen content was by micro-kjedahl method (Jackson, 1962), total phosphorus was by Bray 1 method (Bray and Kurtz, 1945). Calcium (Ca) and magnesium (Mg) were determined by the Atomic Absorption Spectrophotometer (AAS) and potassium (K) and sodium (Na) by flame emission photometry. The organic carbon was according to Walkley and Black (1934) and the present organic matter was estimated by multiplying the percent organic carbon with a factor 1.724. The soil has the following characteristics; pH (in H₂O) 5.0, organic carbon 1.29%, Total N 0.24%; extractable P 4.94 mg Kg⁻¹, extractable K 0.11, Ca 1.62 and Mg 0.59 in cmol Kg⁻¹. Soil particle size distribution

was sand 47%, clay 31% and Silt 22%. The soil was classified as sandy ultisol (Ibe, 2005). The soils have low mineral reserves and are therefore of low fertility. Climatic data was obtained from the Federal University of Technology meteorological unit, Owerri, Nigeria.

The land was ploughed each year and harrowed with the aid of tractor mounted implements. Three varieties of okra were used: NHAe47-4, Lady's finger and V₃₅. NHAe47-4 bred by the National Horticultural Research Institute (NIHORT) Ibadan, Nigeria is characterized by early flowering with thick fresh pods, short to medium in height and with deeply lobed leaves and profuse branching were indicated to be positively geotropic (NIHORT, 1986). Lady's finger is an elite variety popular to the people of the South-Eastern Nigeria, is known to be early flowering, medium in height with nearly entire leaf margin and branches diagonally upwards at an angle of 45° with the main stem. Seeds were obtained from Imo State the Agricultural Development Project (ADP), Owerri, Nigeria. V₃₅ is an adapted exotic variety with almost the same morphological features as the NHAe47-4 was obtained from the National Horticultural Research Institute, Ibadan, Nigeria.

The seeds were treated with *Peperomia pellucida* leaf powder at 30g per 100 seeds as recommended by Ibe *et al.* (1998). Three seeds per hole of the varieties under trial were planted on May 26th in both years on the flat with a spacing of 0.6m x 0.3m between and within the rows respectively and later thinned to one plant/stand. The gross and net plot sizes were 12m² and 6m² respectively.

A commercial formulation of NPK fertilizer (15-15-15) was applied at the rate of 200kg ha⁻¹ to the okra plots, in two equal doses at 2 and 6 WAS. There were five weeding regimes: weedy check, regular weeding up to 5 weeks after sowing (WAS), weeding once at 3 WAS, weeding once at 4 WAS and weed free. Treatments were arranged in a split plot design with variety as main plot factor and weeding regime as sub-plot factor with three replications giving a total of 45 plots. Insect pests were controlled by spraying with cypermethrin to check the incidence of insect pests that affect the leaves of okra plant.

Growth and yield parameters determined were plant height, leaf area, number of flowers produced and aborted, fresh fruit yields, weed density, weed dry weight and weed control efficiency. Weed density was measured by a 1x1m quadrat thrown at random and the weed species within the quadrat counted. Weed control efficiency was calculated based on the method suggested by Bhattacharya and Mandal (1988) as follows:

$$\frac{\text{Dry weed weight (DWT) of unweeded control} - \text{DWT of treatment}}{\text{DWT of unweeded control}} \times 100$$

The data collected were subjected to analysis of variance (ANOVA) and means compared using the Duncan Multiple Range Test (DMRT) at a probability level of 5% according to Gomez and Gomez (1984).

III. RESULTS AND DISCUSSION

a) Growth parameters

The result of the growth parameters of the three okra varieties and the weed interference duration in 2007 and 2008 are presented in Tables 1 and 2. The growth parameters were significantly affected by the okra variety and the different weeding regime. In both years, Lady's finger was significantly taller than the other two varieties. This is in conformity with the growth habits of the cultivars already stated. NHAe47-4 produced significantly larger leaves, more flowers formed and aborted than the rest of the cultivars. Adejonwo *et al.* (1989) observed insignificant growth parameters of V_{35} , TAE-30 and TAE -38 varieties of okra during the dry season while Majanbu *et al.* (1988) reported significant growth characters of NHAe47-4 and white velvet tested under rain fed conditions at Samaru. This is in line with the finding of Majanbu *et al.* (1988) indicating that the season of planting okra plays an important role in determining the growth characters of okra variety.

Duration of weed interference significantly affected okra growth parameters. The unweeded okra plots produced the shortest plants, smallest leaf size and number of flowers produced. Plant height and leaf size from the unweeded plots were not significantly different from plots weeded at 4 WAS or kept weed free till 5 WAS. This indicates that weed interference till 4 WAS had an adverse effect on these growth parameters. The result further showed that in both years keeping weeds in okra plots beyond 3 WAS led to a higher flower abortion which could possibly affect fruit formation negatively. This once again proof that the critical period weed interference is up to 3 WAS. This in agreement with the earlier report of Adejonwo *et al.* (1989) that allowing okra plots to experience weed interference beyond 3 WAS will have adverse effect on okra plants. This is also in line with the report of Scott *et al.* (1979), Ayeni and Oyekan (1992) and Dada and Fayinminnu (2007), that most crops have certain range of tolerance to weed competition and length of period in which they are required to be weed free. Allowing weeds to interfere with crops longer than necessary have always caused yield reduction in crops.

IV. FRUIT YIELD

In both years fruit yield parameters of okra were significantly influenced by the various cultivars (Tables 1 and 2). Fruit yield of NHAe47-4 was higher than the other varieties. While there was no statistical difference in fresh fruit yield/plant between NHAe47-4 and Lady's finger but in fruit yield/hectare, NHAe47-4 and V_{35} in 2007 and 2008 produced more fruits than lady's finger.

Yields of NHAe47-4 and V_{35} did not differ significantly. The better performance of NHAe47-4 and V_{35} among other factors can be attributed to the larger leaf area of both varieties. Ibe *et al.* (2005) recorded a higher utilization efficiency of NHAe47-4 than V_{35} and Lady's finger. NHAe47-4 bred by NIHORT produced higher yield than V_{35} an exotic variety having the same morphological features as that of NHAe47-4 and is well suited to our environment. This is further buttressed by the larger leaf sizes produced by these cultivars which enabled them to produce greater assimilates during their photosynthetic activities. Crop yield in 2007 was generally higher than that of 2008. This is attributed to the poor rainfall experienced in 2008.

V. WEED CONTROL

The prevalent weed types at the experimental site in 2007 and 2008 was dominated by Asteraceae, Cyperaceae, Euphorbiaceae, Poaceae and to a lesser degree Urticaceae and Verbenaceae families (Table 3).

Weed dry weight, weed density and weed control efficiency significantly affected the performance of the okra cultivars (Table 4). NHAe47-4, however, had a better weed control (80.63 and 76.97% in 2007 and 2008 respectively) invariably would lead to less competition from the weeds for growth resources on the field. Allowing the weeds to stay longer with the crops led to higher quantity of weeds produced and subsequently lower weed control ability.

There was no significant difference in weed control efficiency obtained by weeding at 3 WAS (75.13 and 74.47% in 2007 and 2008 respectively) and keeping weed free till harvest. Furthermore, it was observed that there was no significant difference in weed density from the unweeded plots and keeping the plots weed free till 5 WAS. This might suggest that allowing the plots weed free till 5 WAS had accumulated enough growth resources for the weeds to grow vigorously after this period.

Interactive effects between the okra varieties and duration of weed interference were significant (Tables 5 and 6). The lowest okra yields were obtained in weed infested plots till harvest in each of the cultivars. At the early stage of crop growth, both weed and okra nutrients demand are usually met, but as growth progresses, the nutrients supply normally falls short of demand resulting in competition. The plots with better weed control also resulted into higher fruit yield. Ibe *et al.* (2008) had reported that increasing the mulching rate of siam weed in okra led to a better weed control and higher crop yield. NHAe47-4 had a better weed control not significantly different from the weed free plots and performed better than the rest of the cultivars when weeded at 3 WAS. This is due to a reduced competition for resources like nutrients, water and light. The reverse was the case of the unweeded plots with lower weed control and consequently a reduction in crop yield. This



is in agreement with the finding of Fabro and Rhodes (1980) that high weed infestation brings about severe competition for light which will reduce the stomata number, photosynthetic ability of the crop and ultimately the yield. The non weeding would have a shading effect and also a reduction in the photosynthetic ability of the okra. There was higher performance of the cultivars generally at 3 WAS apart from the weed free plots. This is perhaps because nutrients are made available to the crop throughout the growth stages with little or no competition by weeds at this weeding regime. Dada and Fayinminni (2007) suggested that the weeding possibly coincides with the phase when nutrients needed for metabolic processes are made available and utilized to manufacture food. This therefore showed that efficient uptake and utilization of applied nutrients for okra growth, development and yield is a function of the timing of weed infestation and cultivar type.

VI. CONCLUSION

The work revealed that NHAe47-4 with weeding carried out at 3 WAS is better for the growth and yield of okra in South-Eastern Nigeria. This will be advantageous on the poor resources farmers who are the major food producers in this zone of the country.

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Table 1 : Effect of okra varieties and weed interference duration on growth parameters and yield in 2007

Treatments:	Plant height at harvest (cm/plant)	Leaf area/ plant/(cm ²)	No. of flowers formed/plant	No. of flowers aborted/plant	Fresh fruit wt/plant(g)	Fruit yield (tha ⁻¹)
Okra – Cultivars						
NHAe47-4	71.2b ²	38.2a	13.7a	2.4a	28.62a	23.63a
Lady's finger	86.7a	33.4b	11.6b	1.9ab	23.93a	20.48b
V ₃₅	68.9b	36.1a	13.4a	2.2a	19.46	22.94a
Mean	75.6	35.9	12.9	2.17	24.00	22.35
SE (°)	9.7	2.4	1.11	0.2	4.6	1.7
Weed Interference duration						
Weedy check	33.8c	18.2b	6.7c	3.1a	1.08d	6.72d
Weed infested for 3WAS ¹	61.0b	34.6a	11.3a	2.3b	18.06b	22.16a
Weed Infested for 4 WAS	37.1bc	29.9b	8.9b	3.2a	14.79b	13.98b
Weed free until 5 WAS	46.9b	22.1b	7.2b	3.3a	3.80c	10.24c
Weed free until harvest	69.2a	38.2a	13.4a	2.4b	21.21a	24.20a
Mean	49.6	28.6	9.5	2.9	11.79	15.46
SE (°)	15.2	8.4	2.8	0.3	8.98	7.53

Table 2 : Effect of okra varieties and weed interference duration on growth parameters and yield in 2008

Treatment:	Plant height at harvest (cm/plant)	Leaf area plant/ (cm ²)	No. of flowers formed/plant	No. of flowers aborted/plant	Fresh fruit wt/plant (g)	Fruit yield (tha ⁻¹)
Okra – Cultivars						
NHAe47-4	70.0b ²	36.7a	12.8a	2.4a	26.46a	22.96a
Lady's finger	86.3a	32.2b	10.6b	1.8b	22.81a	19.38b
V ₃₅	68.6b	36.1a	12.6a	2.2a	18.63b	22.34a
Mean	74.97	35.0	12.0	2.13	22.63	21.56
SE (°)	8.03	1.99	0.9a	0.25	3.22	1.56
Weed Interference duration						
Weedy check	33.6bc	17.96	5.8c	3.0a	1.05d	6.24c
Weed infested for 3WAS ¹	60.4a	33.8a	10.4a	2.2b	17.26b	20.43c
Weed Infested for 4 WAS	36.7b	28.4ab	8.5b	3.1a	14.07b	13.73b
Weed free until 5 WAS	46.2b	20.7b	6.9b	3.2a	3.29c	9.54c
Weed free until harvest	48.8a	36.2a	12.6a	2.0b	19.33a	22.12a
Mean	49.14	27.4	8.84	2.7	11.00	14.41
SE (°)	13.55	9.79	2.44	0.50	7.44	6.11

Table 3 : Cumulative weed flora composition of the experimental site in 2007 and 2008

Weed types	Plant family	Growth form	Degree of occurrence
<i>Amaranthus spinosus</i>	Amaranthaceae	ABL	XX
<i>Celosia loxa</i>	Amaranthaceae	ABL	XX
<i>Ageratum conyzoides</i>	Asteraceae	ABL	XX
<i>Aspilia africana</i>	Asteraceae	PBL	XX
<i>Chromoleana odorata</i>	Asteraceae	PBL	XXX
<i>Tridax procumbens</i>	Asteraceae	ABL	XX
<i>Commelina benghalensis</i>	Commelinaceae	PSB	XX
<i>Commelina diffusa</i>	Commelinaceae	PSB	XX
<i>Cyperus rotundus</i>	Cyperaceae	PS	XXX
<i>Cyperus tuberosus</i>	Cyperaceae	PS	XX
<i>Euphorbia heterophylla</i>	Euphorbiaceae	ABL	XXX
<i>Phyllanthus amarus</i>	Euphorbiaceae	ABL	XX
<i>Mimosa pudica</i>	Leguminosae	PBL	X
<i>Sida acuta</i>	Malvaceae	PBL	X
<i>Boerhavia diffusa</i>	Nyctaginaceae	PBL	XX
<i>Axonopus compressus</i>	Poaceae	PG	XXX
<i>Cynodon dactylon</i>	Poaceae	PG	X
<i>Eleusine indica</i>	Poaceae	AG	XX
<i>Eragrostis atrovirens</i>	Poaceae	PG	XX
<i>Paspalum conjugatum</i>	Poaceae	PG	XX

<i>Panicum maximum</i>	Poaceae	PG	X
<i>Sporobolus pyramadalis</i>	Poaceae	PG	XX
<i>Talinum triangulare</i>	Portulacaceae	PBL	XX
<i>Diodia scandiens</i>	Rubiaceae	PBL	X
<i>Mitracarpus villosus</i>	Rubiaceae	ABL	XX
<i>Physalis angulata</i>	Solanaceae	ABL	X
<i>Laportea aestuans</i>	Urticaceae	ABL	XX
<i>Starchytapheta cayenensis</i>	Verbenaceae	PBL	XX

Table 4 : Effect of okra varieties and weed interference duration on weed dry weight, weed density and weed control efficiency in 2007 and 2008

Treatments:	Weed dry weight (kg ha ⁻¹)		weed density (no/m ²)		weed control efficiency (%)	
	2007	2008	2007	2008	2007	2008
Okra – Cultivars						
NHAe47-4	91b	111b	20c	23b	80.63a	76.97a
Lady's finger	163a	180a	26a	26a	65.32b	62.66b
V ₃₅	154ab	166b	23b	24a	67.23	65.56b
Mean	136	152.33	23	24.33	71.06	68.40
SE ($\pm$)	25.32	19.92	2.45	2.16	3.3	2.5
Weed Interference duration						
Weedy check	530a	582a	33a	33a	-	-
Weed infested for 3WAS ¹	518b	526b	14b	15b	75.13a	74.47a
Weed Infested for 4 WAS	524b	540b	17b	18b	51.41bc	50.98bc
Weed free until 5 WAS	556a	577a	26a	28a	24.40c	23.83c
Weed free until harvest	0c	0c	0c	0c	100a	100a
Mean	293.60	359.00	18	18.80	62.74	62.32
SE ($\pm$)	38.31	38.10	11.22	11.44	28.02	28.18

Table 5 : Interaction between okra varieties and weed interference duration on growth parameters and yield in 2007

Treatments:	Plant height at harvest (cm/plant)	Leaf area/ plant/(cm ²)	No. of flowers formed/plant	No. of flowers aborted/plant	Fresh fruit wt/plant(g)	Fruit yield (tha ⁻¹)
NHAe 47-4 weedy check	48.4c	22.4b	7.1c	3.4a	1.58d	6.94de
Weed infested for 3 WAS	70.3b	36.6a	12.3a	2.2b	26.84a	23.42a
Weed infested for 4 WAS	63.8b	31.8b	10.7b	3.1a	22.45a	18.34b
Weed free until 5 WAS	51.6bc	26.4b	8.8b	3.5a	5.01c	11.44c
Weed free until harvest	73.4b	40.2a	14.3a	2.2b	29.12a	24.62a
Lady's finger weedy check	54.2bc	23.4b	6.7c	3.2a	1.30d	6.34e
Weed infested for 3 WAS	90.9a	35.6a	11.8b	2.8ab	18.24b	18.86b
Weed infested for 4 WAS	72.4b	32.6ab	10.6b	3.4a	17.04b	15.34c
Weed free until 5 WAS	62.6b	26.3b	8.2b	3.5a	4.23c	10.03d
Weed free until harvest	97.3a	39.1a	14.3a	2.6ab	22.16a	19.65b
V ₃₅ weedy check	46.4c	22.7b	6.8c	3.3a	1.64d	6.69d
Weed infested for 3 WAS	69.80	36.8a	12.6a	2.7ab	23.85a	21.26a
Weed infested for 4 WAS	50.6bc	31.3b	10.2	3.3a	21.14b	16.31b
Weed free until 5 WAS	48.4c	25.3b	7.9c	3.7a	6.04c	9.73c
Weed free until harvest	72.0b	38.4a	14.6	2.5b	26.56a	23.39a
Mean	64.8	28.8	10.5	3.0	15.14	15.68
SE (°)	15.5	14.1	2.6	0.64	10.60	6.48

Table 6 : Interaction between okra cultivars and weed interference duration on growth parameters and yield in 2007

Treatments:	Plant height at harvest (cm/plant)	Leaf area/ plant/(cm ²)	No. of flowers formed/plant	No. of flowers aborted/plant	Fresh fruit wt/plant(g)	Fruit yield (tha ⁻¹)
NHAe47- 4 Weedy check	47.2c	21.8b	6.3c	3.2a	1.53cd	6.82de
Weed infested for 3WAS	69.1b	35.6a	11.4a	2.2ab	26.30a	22.92a
Weed infested for 4 WAS	63.6b	30.4a	9.8b	3.0a	21.74a	17.87b
Weed free until 5 WAS	50.6c	24.3b	7.40c	3.4a	4.89c	10.34d
Weed free until harvest	72.4b	38.3a	13.9a	2.0ab	27.20a	23.40a
Lady's finger Weedy check	53.7c	20.6b	6.0c	3.2a	1.27cd	6.02e
Weed infested for 3 WAS	88.2a	33.8a	11.0b	2.6ab	18.12b	17.86b
Weed infested for 4 WAS	70.1b	30.1a	9.4b	3.3a	15.88b	14.26c
Weed free until 5 WAS	61.4b	24.1b	7.0b	3.4a	3.98c	19.06b
Weed free until harvest	96.4a	36.5a	13.5a	2.5a	20.42a	18.44b
V ₃₅ Weedy check	45.3c	21.6b	6.0c	3.2a	1.46cd	6.24de
Weed infested for 3 WAS	68.3b	35.3a	11.0b	2.6ab	22.06a	19.98ab
Weed infested for 4 WAS	49.8c	30.1a	9.8b	3.2a	19.82b	15.69c
Weed free until 5 WAS	46.8c	24.25	7.6bc	3.6a	4.21c	9.47d
Weed free until harvest	70.6b	37.9a	13.8a	2.4ab	24.63a	22.40c
Mean	63.57	33.78	11.68	3.0	14.23	14.72
SE (°)	14.72	15.26	9.46	0.13	2.51	1.57

Table 7: Interaction between okra cultivars and weed interference duration on weed dry weight, weed density and weed control efficiency in 2007 and 2008

Treatments:	Weed dry weight (kg ha ⁻¹)		weed density (no/m ²)		weed control efficiency (%)	
	2007	2008	2007	2008	2007	2008
NHAe47– 4 Weedy Check	590a	625a	32a	32	-	-
Weed infested for 3WAS	103e	118e	12d	14cd	82.54a	81.12a
Weed infested for 4 WAS	263d	275d	14cd	16c	55.42b	56.00b
Weed free until 5 WAS	415bc	430bc	24b	25b	29.66c	31.20c
Weed free until harvest	0f	0f	0e	0e	100a	100a
Lady's finger Weedy check	630a	642a	38a	38a	-	-
Weed infested for 3 WAS	197d	220d	12d	12d	68.73a	68.85b
Weed infested for 4 WAS	358c	373c	18c	20c	43.17b	41.90c
Weed free until 5 WAS	460b	483b	28a	27b	26.98c	24.77cd
Weed free until harvest	0f	0f	0e	0e	100a	100a
V ₃₅ Weedy check	604a	625a	35a	36a	-	-
Weed infested for 3 WAS	122e	134e	19c	19c	79.82a	78.56a
Weed infested for 4 WAS	268d	281d	14cd	14cd	55.63b	55.04b
Weed free until 5 WAS	504b	528b	26ab	25b	16.55d	15.52e
Weed free until harvest	0f	0f	0e	0e	100a	100a
Mean	275.60	316.40	18.13	18.5	62.73	62.32
SE ([‡])	63.35	50.86	12.00	12.11	43.71	29.90



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Morphometric and Landmark Based Variations of *Apis mellifera* L. Wings in the Savannah Agro - Ecological Zone of Nigeria

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Keywords : *Apis mellifera*, Wing landmarks, Morphometric features, Morphoclusters.

GJSFR-D Classification : FOR Code: 070101, 070102, 070105



MORPHOMETRIC AND LANDMARK BASED VARIATIONS OF *APIS MELLIFERA* L. WINGS IN THE SAVANNAH AGRO- ECOLOGICAL ZONE OF NIGERIA

Strictly as per the compliance and regulations of :



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Morphometric and Landmark Based Variations of *Apis mellifera* L. Wings in the Savannah Agro-Ecological Zone of Nigeria

Oyerinde, A. A.^α, Dike, M. C.^σ, Banwo, O. O.^σ, Bamaïyi, L. J.^σ & Adamu, R. S.^σ

Abstract - This study was aimed at identifying the ecotype *Apis mellifera* subspecies in the savannah vegetation zone of Nigeria based on wing morphology and landmarks variations of samples collected from five States of savannah agro-ecological zone in the country. The measured variables were subjected to analysis with parametric statistic tools of mean, standard deviation and standard error. The distribution and relation between them were subjected to two step cluster analysis. Morphoclusters means were presented in centroids and also the simultaneous confidence intervals (95%) of means values of wing morphometric and landmarks were expressed. Savannah vegetation honeybee samples were classified into two distinct morphoclusters. Morphoclusters 1 constituted 56.4% of honeybees in the region while morphoclusters 2 had 43.6%. The within cluster percentage of state of honeybee showed all honeybee samples collected from Kebbi (100%) State were of morphoclusters 1 and also, morphoclusters 2 in Kaduna (100%) and Kwara (100%) States. On the contrary, Abuja (88%) and Adamawa (94%) recorded majority of their honeybees in morphoclusters 1. Twenty as well as six landmarks occurred on the fore and hindwings of the two morphoclusters respectively. The outcome of this research revealed that variations in wing morphometric features and landmarks of honeybee workers can serve as a veritable tool for grouping *Apis mellifera* species in savannah agro-ecological zone of Nigeria into subspecies.

Keywords : *Apis mellifera*, Wing landmarks, Morphometric features, Morphoclusters.

I. INTRODUCTION

Systematic is a part of the scientific practice known as taxonomy, it involves the use of evolutionary relationships to classify organisms. Classification of insect is done with varying different techniques based on the methods adopted by the taxonomist. Methodology of engaging differences in wing morphology and landmarks by insect taxonomists gave successful identification of insect population into specified races and portray the variations within the specific discriminants (Mendes *et al.*, 2007).

Apiculture entails the management and maintenance of colonies of honeybees (Parker, 1981). Honeybees especially members of the family Helictidae

are social insects that exist in colonies. They are kept for highly desirable products such as honey, comb/wax, pollen, propolis, bee venom and royal jelly (Ojeleye, 1999). Historically, anywhere from six to eleven species of honeybees have been recognized (Engel, 1999).

Determination of the subspecies of honeybee in Nigeria is necessary based on the existing discordance of records on the races of honeybees reared in modern apicultural practices in the country. Also, studies on the influence of vegetation distribution on the diversity of honeybee races in the savannah agro-ecological zone of the country have not yet been conducted. This study was aimed at identifying the ecotype *Apis mellifera* subspecies in the savannah vegetation zone of Nigeria based on wing morphology and landmarks variations of samples collected from five savannah agro-ecological zone of the country.

II. MATERIALS AND METHODS

a) Study Site and Collection of Sample

Samples of 7500 honeybee workers were collected from 250 colonies of the savannah agro-ecological zone of Nigeria. Thirty honeybee workers were collected from 50 colonized hives from apiaries in Ilorin (Kwara State), Abuja (FCT), Katari (Kaduna State), Mayo Belwa (Adamawa State) and Zuru (Kebbi State) of Nigeria. Collection of research bees was done from colonies formed by captured swarms and unmanaged for queen replacement. The samples were stored and labelled separately in 70% ethanol container according to their State of collection. These were used for wing morphology and landmarks multivariate analysis in the laboratory.

b) Morphometric Studies

Laboratory analysis of the wing morphology and landmarks was performed on ten randomly selected samples of honeybee workers obtained from the five savannah vegetation States based on methods used in morphometric analyses of *A. mellifera* (Andere *et al.*, 2008) and use of wing landmarks in classifying bumble bees into subspecies (Aytekin, *et. al.*, 2007). Calibrated hand held digitalised MiScope microscope with magnification range of 40-140x was used in measurement of wing morphometric and landmarks

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features in millimetres and replicated thrice. The measured variables includes : The length of the hindwing (LHW), width of the hindwing (WHW), length of the forewing (LFW), width of the forewing (WFW), number of landmarks on the forewing (NLF), number of landmarks on the hindwing (NLH), number of landmarks on the radial cell of the forewing (NLR), length of radial cell (LRC) and width of radial cell (WRC). Raw data for the statistical analysis was obtained from the carefully recorded wing morphometric and landmarks data measured per hive.

c) Data Analysis

Analysis of the wing morphology and landmarks data was achieved with SPSS statistic 17 software. Parametric statistic tools of mean, standard deviation and standard error were engaged to differentiate the honeybee samples while the distribution and relation between them were subjected to two step cluster analysis. The morphoclusters means were presented in centroids and also, the simultaneous confidence intervals (95%) of means of wing morphometric and landmarks variables were expressed in charts.

III. RESULTS

Grouping of savannah vegetation honeybee samples based on wing morphometric and landmarks classified all samples into two distinct morphoclusters. Morphoclusters 1 constituted 56.4% of the honeybee's samples encountered in the savannah agro-ecological zone of Nigeria (Table 1) while the remaining 43.6% formed morphoclusters 2. The within cluster percentage of state of honeybee morphoclusters based on wing morphometric features and landmarks (Table 2) showed that all honeybee samples collected from Kebbi (100%) State were of morphoclusters 1 and also, this trend occurred in distribution of honeybees of morphoclusters 2 in Kaduna (100%) and Kwara (100%) States. Abuja (88%) and Adamawa (94%) recorded majority of their honeybees in the morphoclusters 1 while, the remaining percentages of honeybees i.e. 12% and 6% formed morphoclusters 2 respectively.

Wing morphological differences that exist in the two morphoclusters of honeybees from encountered in the zone (Table 3) revealed that LHW (2.44mm), WHW (0.66 mm) LFW (3.59 mm), NLF (20), LRC (1.30 mm) and WRC (0.19 mm) obtained in morphoclusters 1 were higher than the values of morphoclusters 2 while, the remaining morphometric features had their peaks in morphoclusters 2 except, NLR that had a uniform (5) number of landmarks.

Morphoclusters 2 had mean intervals above the overall means and morphoclusters 1 in LHW, WHW, LFW, LRC and WRC, as well as, 20 landmarks that occurred on the forewings while, morphoclusters 1 had higher mean interval in WFW and number of landmarks

on the hindwing (Fig. 1). On the contrary, all NLR obtained from the two morphoclusters were the same with the overall mean.

IV. DISCUSSION

Honeybee taxonomy can be affected by a number of factors, especially agro-ecological zone. Results obtained from this study revealed that honeybee samples collected from various States in the savannah vegetation zones of Nigeria formed two different morphoclusters. The variations that occurred in the wing morphometric features of honeybees from different States and relativity of some of the features from the same state could be deduced to similarity of biology of honeybee species in the same geographical zone (Winston *et al.*, 1981) while, variations of wing landmarks of *A. mellifera* morphoclusters in the savannah vegetation zone is in line with findings of Mendes, (2007) which reported differences in the wing landmarks of bumble bees collected from the same ecological zone. Two morphoclusters of honeybees obtained in the five savannahs vegetation States indicated high relativity in the wing morphology and landmarks features in the region. This confirmed the influence of geographical location on the distribution of honeybee's subspecies (Sheppard *et al.*, 1997) and portrayed the morphoclusters encountered as having the ability to survive over a wide range of States in the belt. This was in agreement with Amorin and Ribeiro (2001) findings which stated that honeybee species could migrate over wider vegetation belt in search of food (nectar and pollen), water and appropriate nesting site during swarming season or in period of adverse environmental condition.

The number of landmarks (approximately 20) that occurred on the forewing of morphoclusters 1 and 2 (Plate 1) were the same with the findings on bumble bees (Aytekin, *et al.*, 2007) while the record of approximately 6 landmarks (Plate 2) observed on the hindwings of the two morphoclusters showed similarity between the duo. These conform to the result of using morphometric differences of a single wing cell in classifying *Apis mellifera* into racial types (Francoy, *et al.*, 2006). In addition, the wide variations recorded in nearly all the simultaneous confidence intervals of means of morphometric features and landmarks in the two morphoclusters, confirms the existent of differences in the morphometric features and landmarks of the two morphoclusters. Thus, portrays honeybees of the two morphoclusters as having distinct wing morphometric features and landmarks.

Use of wing morphometric features and landmarks variations in classifying *Apis mellifera* into morphoclusters in this study is an indication that this technique can be adopted in discerning honeybees

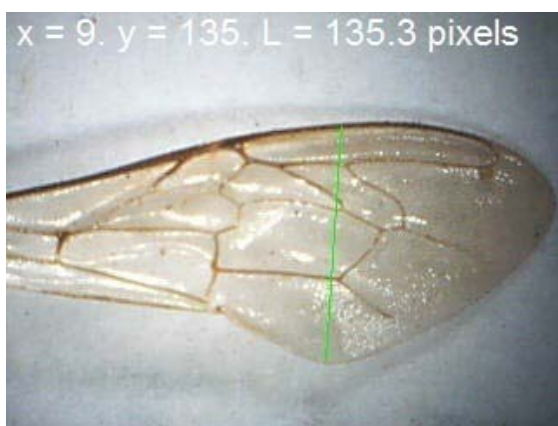


Plate 1 : Twenty Landmarks on Forewing

from this zone into morphoclusters. This is in line with the report of the successful use of morphometric of *A. mellifera* by Andere *et al.*, (2008) and the use of wing landmarks in bumble bees by Aytekin *et al.*, (2007).

V. CONCLUSION

The outcome of this research showed that variations in the wing morphometric features and landmarks of honeybee workers can serve as an effective tool for grouping *Apis mellifera* kept in beekeeping practice in savannah agro-ecological zone of Nigeria into subspecies. Research into the genomic variation of the identified morphoclusters need be encouraged, as this will go a long way to trace the phylogeny relationship of the different honeybee morphoclusters in this zone of the country.

ACKNOWLEDGEMENT

The authors appreciate financial assistance from Science and Technology Education Post Basic Project STEP B (Nigeria) and also Mr Ishiaku P. Musa of the Insect Museum, Department of Crop Protection, Ahmadu Bello University Nigeria for his technical support on the research work.

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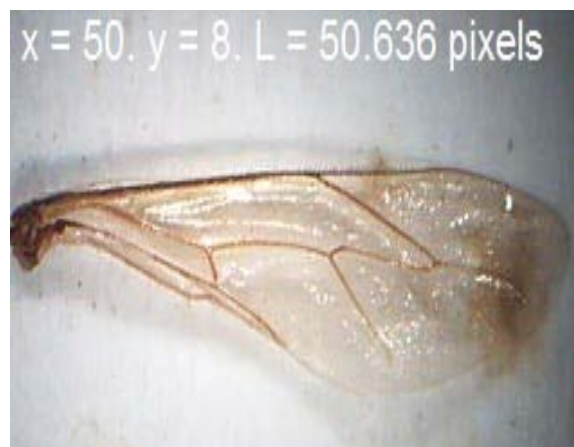


Plate 2 : Six Landmarks on Forewing

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Table 1 : Wing Morphology and Landmarks Based Cluster Distribution of Ecotype *Apis mellifera* Species in the Savannah Vegetation Zone of Nigeria

Cluster	No	% of Combined	% of Total
1	423	56.4%	56.4%
2	327	43.6%	43.6%
Combined	750	100.0%	100.0%
Total	750		100.0%

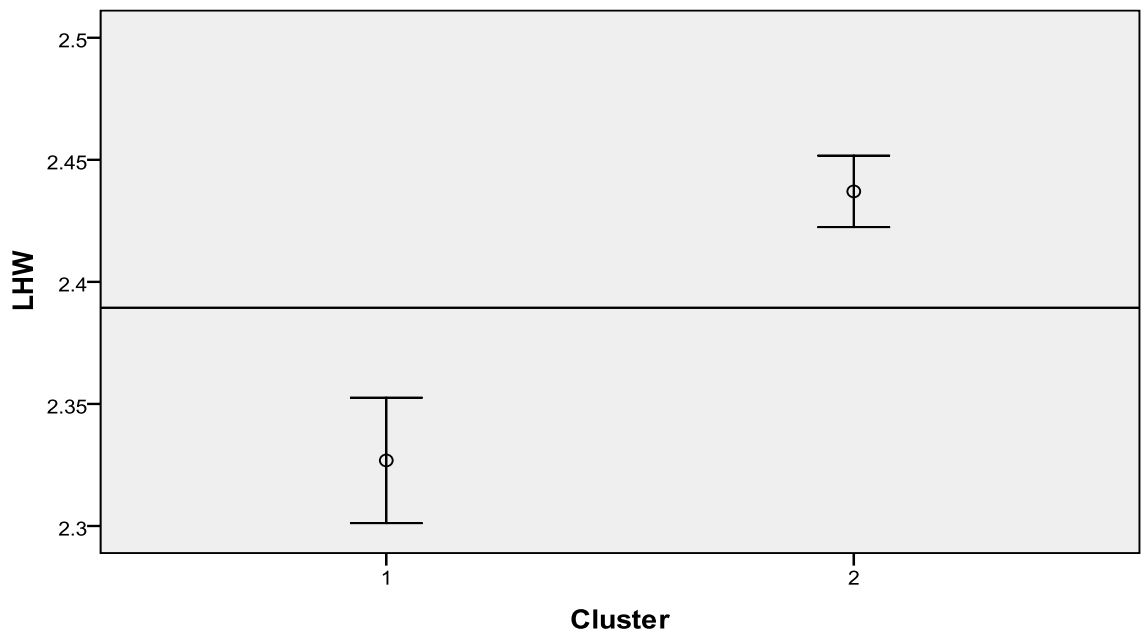
Table 2 : Within Cluster Percentage of State of Ecotype *Apis mellifera* Species Based on Wing Morphology and Landmarks in the Savannah Vegetation Zone of Nigeria

Cluster	Abuja FCT	Adamawa State	Kaduna State	Kebbi State	Kwara State
Frequency Percentage					
1	132	141	94.0%	0	100.0%
2	18	9	6.0%	150	100.0%
Combined	150	150	100.0%	150	100.0%

Table 3 : Centroids of Morphoclusters of Ecotype *Apis mellifera* Species Based on Wing Morphology and Landmarks in the Savannah Vegetation Zone of Nigeria

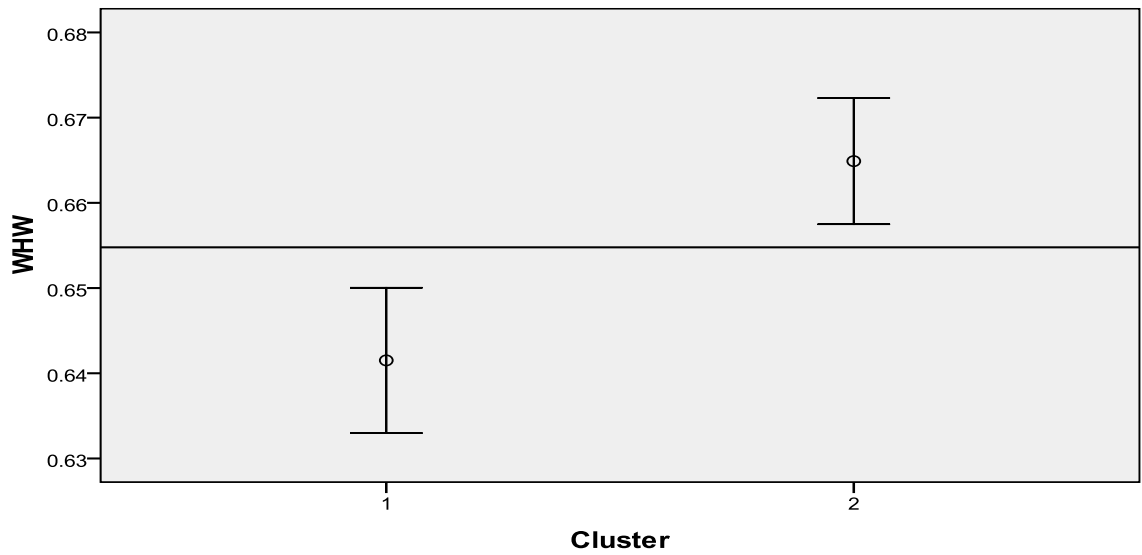
Cluster	LHW (mm)		WHW (mm)		LFW (mm)		WFW (mm)		LRC (mm)		WRC (mm)		NLF		NLH		NLR	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	2.34	0.20	0.64	0.06	3.43	0.16	1.18	0.08	1.27	0.06	0.18	0.01	19.63	0.48	5.65	0.48	5.00	0.00
2	2.44	0.13	0.66	0.07	3.59	0.09	1.17	0.07	1.30	0.06	0.19	0.02	20.00	0.00	5.58	0.49	5.00	0.00
Combined	2.39	0.18	0.65	0.07	3.52	0.15	1.17	0.08	1.29	0.06	0.19	0.02	19.84	0.37	5.61	0.49	5.00	0.00
±SEM	0.01		0.00		0.01		0.00		0.00		0.00		0.01		0.02		0.00	

Length of Hindwing (LHW), Width of Hindwing (WHW), Length of Forewing (LFW), Width of Forewing (WFW), No of Landmarks on Forewing (NLF), No of Landmarks on Hindwing (NLH), No of Landmarks on Radial Cell (NLR), Length of Radial Cell (LRC), Width of Radial Cell (WRC)



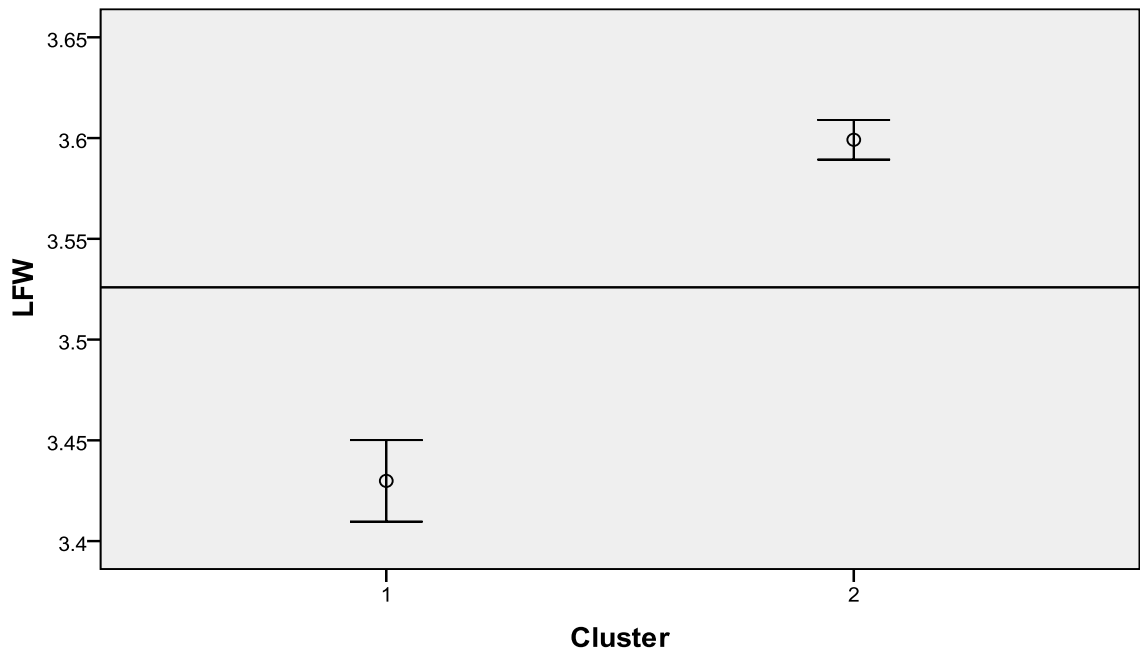
Reference line is the overall mean = 2.39

Figure 1a: Within Cluster Variation of Means of Length Hindwing (LHW)



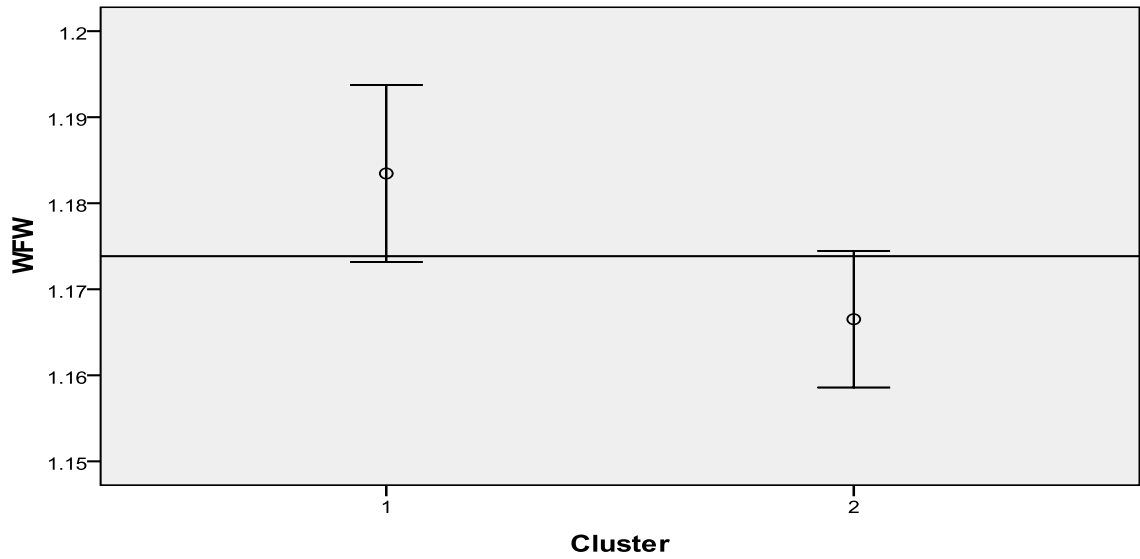
Reference line is the overall mean = 0.65

Figure 1b : Within Cluster Variation of Means of Width Hindwing (WHW)



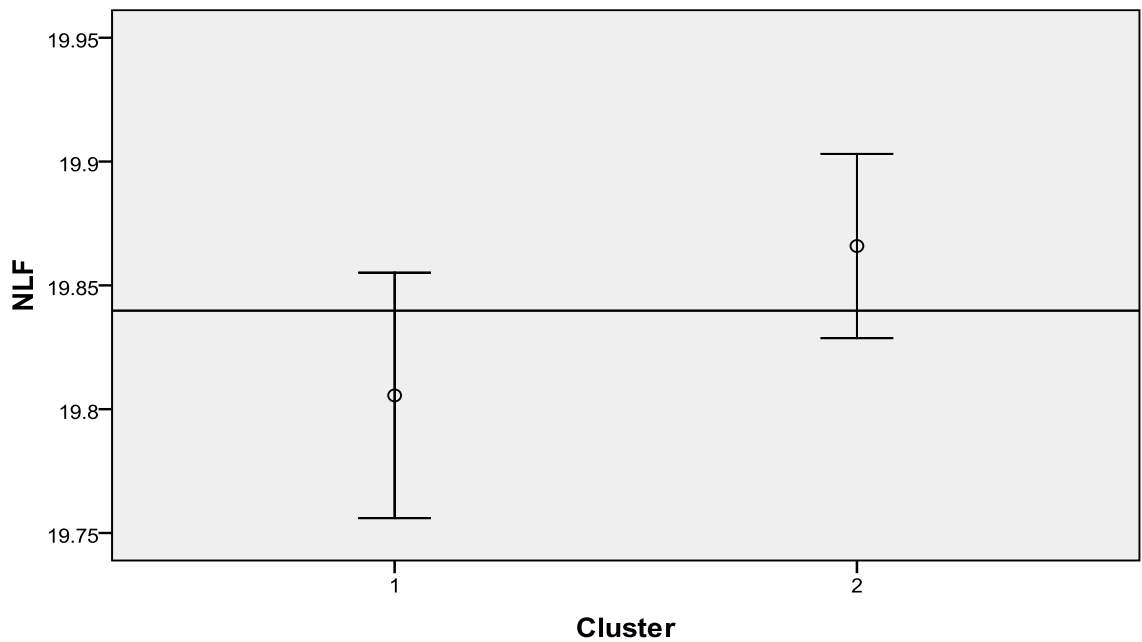
Reference line is the overall mean = 3.53

Figure 1c : Within Cluster Variation of Means of Length Forewing (LFW)



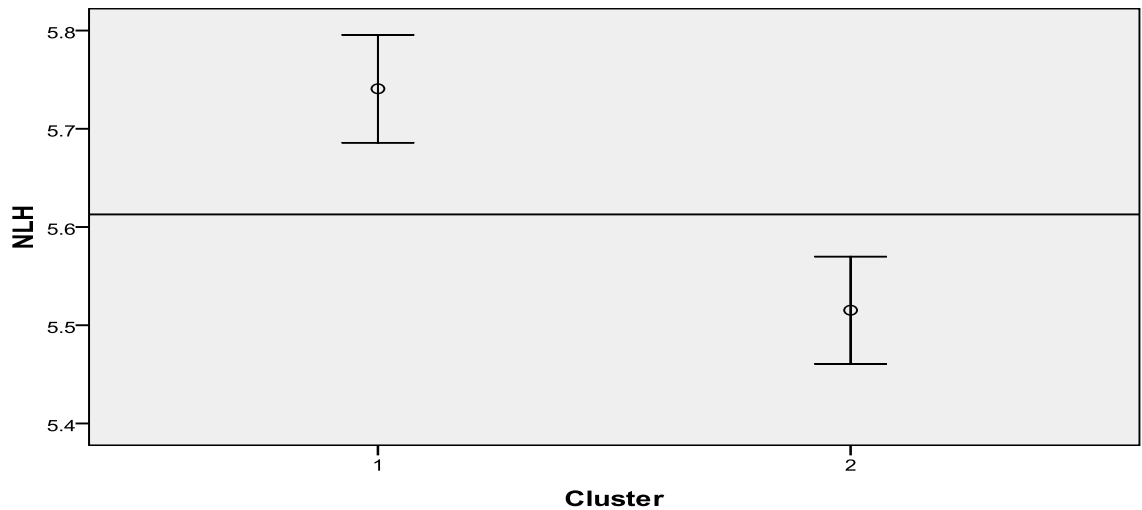
Reference line is the overall mean = 1.17

Figure 1d : Within Cluster Variation of Means of Width Forewing (WFW)



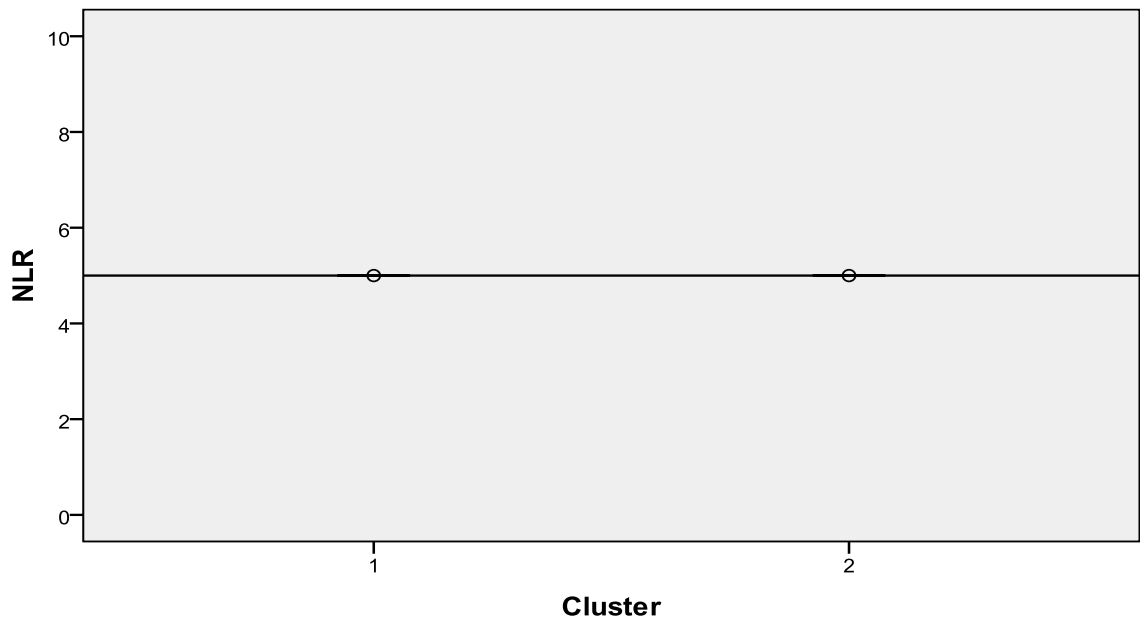
Reference line is the overall mean = 19.84

Figure 1e : Within Cluster Variation of Means of No of Landmarks on Forewing (NLF)



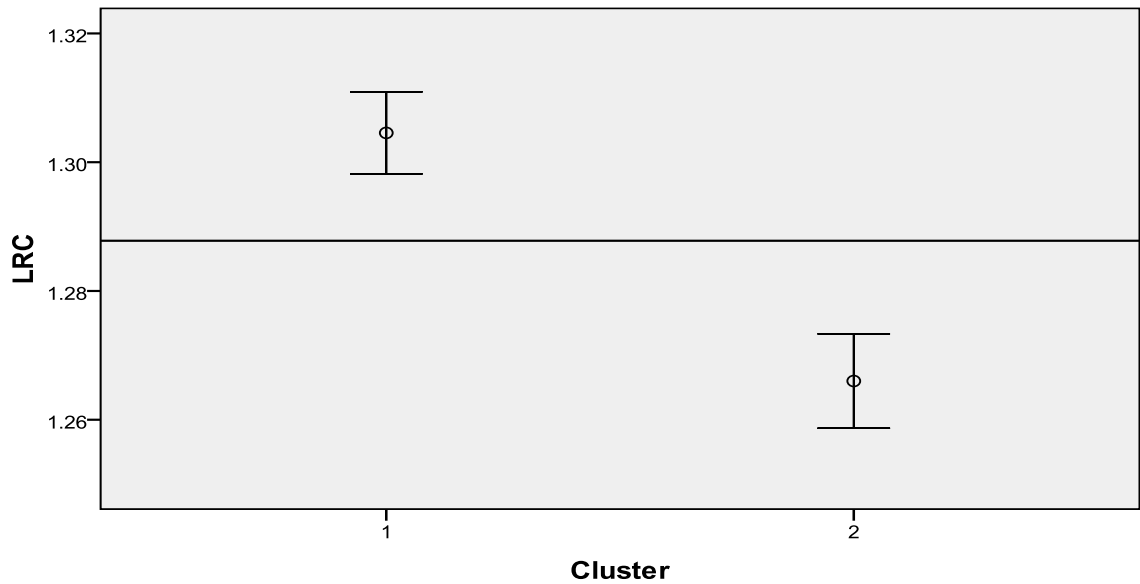
Reference line is the overall mean = 5.61

Figure 1f : Within Cluster Variation of Means of No of Landmarks on Hindwing (NLH)



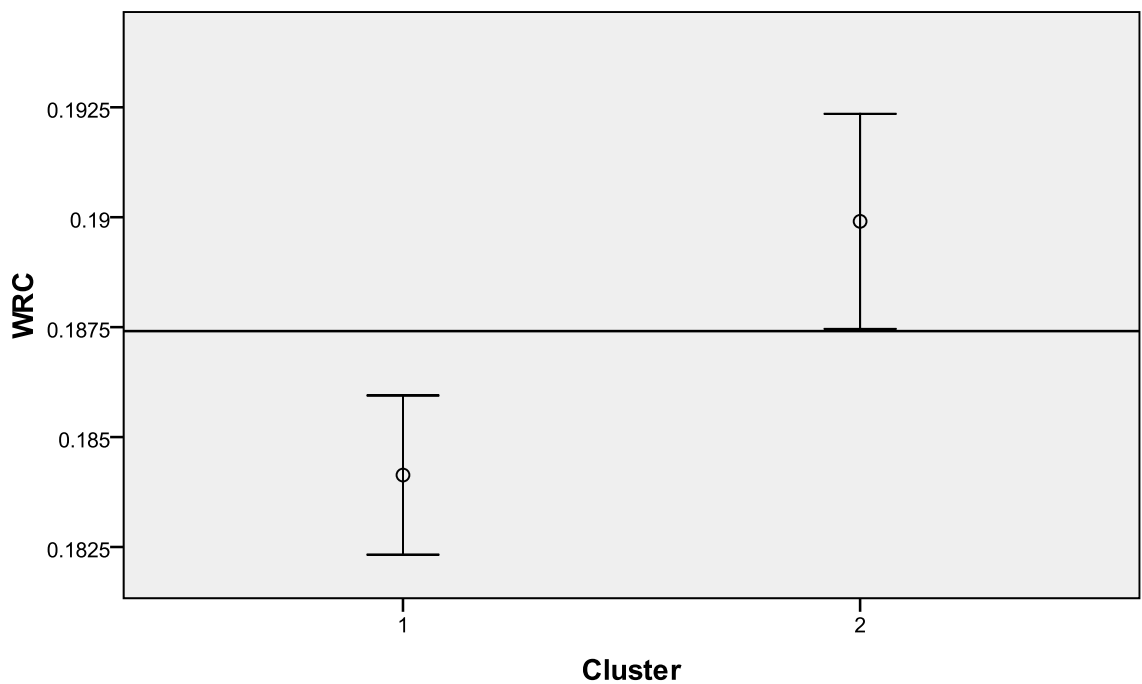
Reference line is the overall mean = 5.00

Figure 1g : Within Cluster Variation of Means of No of Landmarks on Radial Cell (NLR)



Reference line is the overall mean = 1.29

Figure 1h : Within Cluster Variation of Means of Length Radial Cell (LRC)



Reference line is the overall mean = 0.19

Figure 1i: Within Cluster Variation of Means of Width Radial Cell (WRC)

Figure 1: Simultaneous 95% Confidence Intervals of Means of Mophoclusters Based on Wing Morphology and Landmarks Variables in the Savannah Vegetation Zone of Nigeria

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GLOBAL JOURNAL OF SCIENCE FRONTIER RESEARCH
AGRICULTURE AND VETERINARY SCIENCES

Volume 12 Issue 7 Version 1.0 Year 2012

Type : Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals Inc. (USA)

Online ISSN: 2249-4626 & Print ISSN: 0975-5896

Comparative Studies of Behavioural Variations of *Apis mellifera* L. Species in Nigeria

By Oyerinde, A. A., Dike, M. C., Bamaiyi, L. J. & Adamu, R. S.

University of Abuja, Nigeria

Abstract - Studies were conducted for three beekeeping seasons (between 2009 and 2011) on 400 colonized hives sited in the two major vegetation zones of Nigeria. Direct counting of the number of sting bables deposited on the beekeepers kit by scout bees defending her colony was done during the period of routing inspection and harvesting of crops from selected colonies while swarming and abscondment of established colonies after the first visit was noted and recorded for each farm. Behavioural variations of *mellifera* species from the forest and savannah vegetation zones of Nigeria revealed that majority (above 65%) of the honeybees were highly aggressive and none of the colonies in the country was stingless. The preponderance of the deposit of the sting bables by the scout bees in the nation was highly aggressive +++ > aggressive ++ > less aggressive + > stinglessness -. Comparison of behavioural variations of *Apis mellifera* colonies in Nigeria revealed that Abuja (31.3%), Adamawa (4.0%) and Osun (3.3%) States had the less aggressive species of honeybees while, both Kebbi (80.7%) and Ebonyi (79.7%) States recorded the highest percentages of sting bables deposition in the savannah and forest vegetation respectively.

Keywords : *Apis mellifera*, Colonies, Aggressiveness, Swarming, Abscondment.

GJSFR-D Classification : FOR Code: 830502



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Comparative Studies of Behavioural Variations of *Apis mellifera* L. Species in Nigeria

Oyerinde, A. A.^α, Dike, M. C.^σ, Bamaiyi, L. J.^σ & Adamu, R. S.^σ

Abstract - Studies were conducted for three beekeeping seasons (between 2009 and 2011) on 400 colonized hives sited in the two major vegetation zones of Nigeria. Direct counting of the number of sting bables deposited on the beekeepers kit by scout bees defending her colony was done during the period of routing inspection and harvesting of crops from selected colonies while swarming and abscondment of established colonies after the first visit was noted and recorded for each farm. Behavioural variations of *Apis mellifera* species from the forest and savannah vegetation zones of Nigeria revealed that majority (above 65%) of the honeybees were highly aggressive and none of the colonies in the country was stingless. The preponderance of the deposit of the sting bables by the scout bees in the nation was highly aggressive +++> aggressive ++ > less aggressive + > stinglessness -. Comparison of behavioural variations of *Apis mellifera* colonies in Nigeria revealed that Abuja (31.3%), Adamawa (4.0%) and Osun (3.3%) States had the less aggressive species of honeybees while, both Kebbi (80.7%) and Ebonyi (79.7%) States recorded the highest percentages of sting bables deposition in the savannah and forest vegetation respectively. The percentage of abscondment and swarming of established colonies recorded in the country was ebb but, honeybee colonies' abscondment ranged from 0.7% to 4.0% in Kwara and Osun States both in the savannah and forest vegetation zones of Nigeria respectively.

Keywords: *Apis mellifera*, Colonies, Aggressiveness, Swarming, Abscondment.

I. INTRODUCTION

A piculture entails the management and maintenance of colonies of honeybees (Parker, 1981) that are kept for highly desirable products such as honey, comb/wax, pollen, propolis, bee venom and royal jelly (Ojeleye, 1999). Beekeeping was practiced in different ways in Africa in general and Nigeria in particular and in many cases the occupation was associated with some folklore, e.g. the Tiv people believe that beekeeping is a secret practice into which beginners must be initiated before they can practice (Olagunju, 2000). Like all the Agricultural sectors, beekeeping is a noble and economically rewarding vocation that can improve the socio-economic conditions of people in rural areas who do not own land to grow their own subsistence crops (Mahalefele, 1991).

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A colony consists of three castes, infertile female workers, male drones and a queen (Johansson, 1980). The vast majority of adult honeybees in any colony are infertile female worker bees. The jobs of the worker bees are: tending and feeding young bees (larvae), making honey, making royal jelly and bee bread to feed larvae, producing wax, cooling the hive by fanning wings, gathering and storing pollen, nectar and water, guarding the hive, building, cleaning and repairing the comb and feeding and taking care of the queen and drones.

Several researchers and beekeepers had described the general distinguishing traits of the African honeybee subspecies, as rapid population growth, frequent swarming, minimal hoarding of honey, ability to survive on sparse supplies of pollen and nectar and highly defensive nature (Sugden, 2007). They abscond their hives in time when food-store is low, unlike the European colonies, which end dieing in the hives (Winston *et al.*, 1981).

The ability to increase honey production is rested upon several factors among which evaluation of the behavioural differences of races of *Apis mellifera* in Nigeria require top most attention. In Nigeria where a rich nectar flow is found, relatively small quantity of honey are produced and up to date no developmental programme has deemed it fit to conduct studies on the behavioural variations of the races of honeybees in Nigeria in terms of aggressiveness in order to further develop the gentle races that can encourage interested youth and other individuals aimed at engaging in healthy Apicultural practices in the country.

II. MATERIALS AND METHODS

a) Study Site

Studies were conducted for three beekeeping seasons on 400 colonized hives sited in the two major vegetation zones of Nigeria. 50 colonized hives were selected from established honeybee farms in Igbeti (Oyo State), Oshogbo (Osun State) and Ishiagwu (Ebonyi State) in the Forest Agro-ecological zone, as well as, Ilorin (Kwara State), Abuja (FCT), Katari (Kaduna State), Mayo Belwa (Adamawa State) and Zuru (Kebbi State) in the Savannah vegetation zone of the country.

Direct counting of the number of sting bables (Plate 1) deposited on the bee suite, hand gloves and hat by scout bees defending her colony was done during the period of routing inspection and harvesting of

crops from selected colonies over three beekeeping season i.e. between 2009 and 2011 while, swarming and

abscondment of established colonies after the first visit was noted and recorded for each farm.



Plate 1 : Showing Scout Bees Depositing Sting Babels on Hat and Bee suite

The behavioural characteristics was expressed on a range scale defined as: number of sting babel (NSB) i.e. no sting babel or stinglessness (-); 0-20 sting babels or less aggressive (+); 21-50 sting babels or aggressive (++); >50 sting babels or highly aggressive (+++); swarming behaviour (CS) i.e. no swarming (-); colony swarmed (+); abscondment behaviour (CA) i.e. no abscondment (-); colony absconded (+). The behavioural variation of the respective ecotype honeybees observed in the two vegetation zones was analyzed with inferential statistics tools of percentage and variance.

III. RESULTS

Behavioural variations of *Apis mellifera* species from the forest vegetation zone of Nigeria (Table 1) revealed that majority (above 65%) of the honeybees were highly aggressive and none of the colonies in this region was stingless. The preponderance of the deposit of the sting babels by the scout bees in the region was highly aggressive +++ > aggressive ++ > less aggressive + > stinglessness -. Also, the percentage of abscondment and swarming of established colonies in Ebonyi, Osun and Oyo States were relatively low i.e. 2.0, 4.0 and 2.7 respectively.

Hitherto, the behavioural variations of *Apis mellifera* species of the savannah vegetation zone of Nigeria (Table 2) were not different with the result obtained from honeybees of the forest vegetation origin. Majority of the States i.e. Adamawa, Kaduna, Kebbi and Kwara had above 60% honeybees colonies with highly aggressive behaviour but, honeybee colonies of apiaries sited in Abuja were relatively less aggressive compared to those from the various States. The deposition of sting babels by the scout bees of Abuja colonies spread over

the scales of aggressivity i.e. +++ (38%), ++ (30.7%) and + (31.3%).

Likewise as was experienced with the forest region colonies, none of the colonies in the savannah region was stingless. The preponderance of the deposit of the sting babels by the scout bees in this region followed suit with the pattern exhibited in the forest agro-ecological zone of the country. In addition, the percentage of abscondment and swarming of established colonies recorded in the savannah vegetation colonies were lower compared to their forest counterpart. Colonies abscondment and swarming in this region ranged between 0.7% in Kwara State to 2.0% in Abuja FCT, Adamawa and Kebbi States.

Comparison of behavioural variations of *Apis mellifera* colonies from the two main vegetation zones of Nigeria revealed that Abuja (31.3%), Adamawa (4.0%) and Osun (3.3%) States had the less aggressive species of honeybees while, both Kebbi (80.7%) and Ebonyi (79.7%) States recorded the highest percentages of sting babels deposition on bees suite (i.e. highly aggressive) in the savannah and forest vegetation respectively. This implied that colonies from the two States were highly ferocious and beekeepers in these States need proper kitting before inspecting their respective colonies.

In addition, comparison of colonies in terms of presence of stingless honeybee species showed that none of the colonies in the country exhibited this behaviour. The percentage of abscondment and swarming of established colonies recorded in the country was ebb but, honeybee colonies' abscondment ranged from 0.7% in Kwara State in the savannah vegetation zone to 4% in Osun State in the forest vegetation zone of Nigeria. This showed that

beekeepers in Kwara State had the best management practice of their honeybee's colonies.

IV. DISCUSSION

Majority of *A. mellifera* encountered in this study exhibiting high aggressiveness in terms of number of sting bates deposited on beekeepers protective clothing by scout bees was an indication of the various ecotype *A. mellifera* being highly defensive as earlier reported on characteristics of Africanized honeybees by Sheppard *et al.*, (1999) and Sugden, (2007). In addition, the identification of few colonies that was less aggressive in Abuja, Adamawa and Osun States contradicted Sugden, (2007), earlier report that classified Africanized *A. mellifera* species as killer bees. Thus, the less aggressive species that occurred in Abuja, Adamawa and Osun States compared to the other States gave an indication that bees from these States can be adopted in queen rearing programme in order to develop bees that will be friendlier with beekeepers in the country. Also, the low abscondment and swarming rate recorded in this study portrayed effective management and adequate availability of food (pollen and nectar) for established honeybee's colony in the sampled State. This confirmed the concentration of honeybees on honey production when the environmental condition was favourable (Taylor, 1977; Otis *et al.*, 1981).

V. CONCLUSION

Based on our identification of some less aggressive colonies in this study, it is imperative to engage those less aggressive colonies in queen rearing programme, with the aim of producing nucleus bee colonies that can be adopted in modern beekeeping practice in Nigeria, in order to reduce exposure of beekeepers to unwanted bee sting by their respective colonies.

VI. ACKNOWLEDGEMENT

We appreciate financial assistance from Science and Technology Education Post Basic Project STEP B (Nigeria) and also Mr Ishaku P. Musa of the Insect Museum, Department of Crop Protection, Ahmadu Bello University Nigeria for his technical support on the research work.

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Table 1 : Behaviourial Variations of Ecotype *Apis mellifera* Colonies in Forest Vegetation Zone of Nigeria

State	No (%) Sting Babel NSB			No (%) Colony Swarmed CSS			No (%) Colony Absconded CAS		
	-	+	++	+++	Variance	-	Variance	+	Variance
Ebonyi	0(0.0)	0(0.0)	30(20.3)	120(79.7)	0.442	147(98.0)	3(2.0)	0.020	147(98.0)
Osun	0(0.0)	5(3.3)	44(29.3)	101(67.3)	0.802	144(96.0)	6(4.0)	0.039	144(96.0)
Oyo	0(0.0)	0(0.0)	32(21.3)	118(78.7)	0.541	146(97.3)	4(2.7)	0.026	146(97.3)

Number of sting babel **nsb** - no sting babel = stinlessness, + 0-20 sting babel= less aggressive, ++ 21-50 sting babel= aggressive, +++ >50
sting babel highly aggressive, - no swarming, + colony swarmed **css**, -no abscondment, + colony absconded **cas**

Table 2 : Behaviourial Variations of Ecotype *Apis mellifera* Colonies in Savannah Vegetation Zone of Nigeria

State	No (%) Sting Babel NSB			No (%) Colony Swarmed CSS			No (%) Colony Absconded CAS		
	-	+	++	+++	Variance	-	Variance	+	Variance
Abuja	0(0.0)	47(31.3)	46(30.7)	57(38.0)	0.804	147(98.0)	3(2.0)	0.013	147(98.0)
Adamawa	0(0.0)	6(4.0)	50(33.3)	94(62.7)	0.531	147(98.0)	3(2.0)	0.020	147(98.0)
Kaduna	0(0.0)	0(0.0)	32(21.3)	116(77.3)	0.362	148(98.7)	2(1.3)	0.026	148(98.7)
Kebbi	0(0.0)	0(0.0)	29(19.3)	121(80.7)	0.442	147(98.0)	3(2.0)	0.020	147(98.0)
Kwara	0(0.0)	0(0.0)	44(29.3)	106(70.7)	0.297	149(99.3)	1(0.7)	0.007	149(99.3)

Number of sting babel **nsb** - no sting babel = stinlessness, + 0-20 sting babel= less aggressive, ++ 21-50 sting babel= aggressive, +++ >50
sting babel highly aggressive, - no swarming, + colony swarmed **css**, -no abscondment, + colony absconded **cas**

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- (e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.
- (f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;
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- (h) Brief Acknowledgements.
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- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
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References

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Topics	Grades		
	A-B	C-D	E-F
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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ISSN 9755896

