WOOD SPECIES PREFERENCE FOR HONEYBEES COLONISATION IN OYO AND OGUN STATES, NIGERIA

BY

Adebukola Abeke Sherifat, AKINLADE

B.Sc.; M.Sc., Forest Resources Management

(Ibadan)

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ABSTRACT

Wood species are major determinants of bee colonisation and retention, hence influencing the yield and quality of honey produced. In Apiculture, wood species preference for beehive construction has been implicated in high bee abscondment. However, information on the properties of wood species preferred by honeybees is limited. Therefore, properties of preferred wood species for beehive construction and honey production in selected locations from Oyo and Ogun states were investigated.

Structured questionnaire was administered to all active bee farmers in two bee farming communities each in Oyo (Onifuufu: n=20; Ogunmakin: n=12) and Ogun (Adeaga: n=32; Ayetoro: n=16) States. Information on estimated honey production (kg/year) and preferred wood species for beehive construction were elicited. Five most preferred wood species were used to construct twelve (60cm x 30cm x 15cm) wooden hives, each covered with 22 top-bars. Three of the constructed hives per wood species were erected in each of the four communities. Number of colonised top-bars/ hive and abscondment after baiting were obtained monthly for a year. Honey yield per hive (kg/year) was calculated. Physical {density (kg/m^3), moisture content (%), volumetric shrinkage (%)}, and phytochemical {(alkaloids (ppm), flavonoids (ppm) and phenols (μ)} properties of preferred wood species were determined using standard procedures. Data were analysed using descriptive statistics, regression and ANOVA at $\alpha_{0.05}$.

Bee farmers with highest estimated honey production (9.0±0.0 kg) were 45.0% (Onifuufu), 43.8% (Adeaga), 41.7% (Ogunmakin) and 37.5% (Ayetoro) while the least (4.0±0.0) were 6.3%, 6.3%, 8.3% and 10.0% in Adeaga, Ayetoro, Ogunmakin and Onifuufu, respectively. Fifteen wood species were identified for beehive construction. Five most preferred species were *Khaya grandifoliola* (3.7%), *Terminalia superba* (6.3%), *Cordia millenii* (18.8%), *Triplochiton scleroxylon* (21.2%) and *Gmelina arborea* (50%). Colonisation was highest in *G. arborea* beehives at each location (Ogunmakin: 94.4±9.6; Adeaga and Ayetoro: 83.3±16.7; Onifuufu: 77.8±9.6) and least with *K. grandifoliola* (16.7± 28.9 in Ogunmakin and Ayetoro) and *Triplochiton scleroxylon* (33.3±28.9 in Adeaga and 38.9±34.7 in Onifuufu). Abscondment was highest (66.6%) in *K. grandifoliola* (Onifuufu, Ayetoro) and none in *G. arborea*.Highest and least honey yield were 6.7±0.2; 3.6±0.2 (Adeaga), 6.2±0.2; 3.4±0.3 (Onifuufu), 5.6±0.2; 3.4±0.3 (Ayetoro) and 5.4±0.2; 4.1±0.2 (Ogunmakin). Honey yield was highest in *G.*

*arborea*hives (5.9±1.0) and least in *K. grandifoliola* (3.6±0.1). *Khaya grandifoliola* had the highest (611.6±70.7) density while *T. superba* had the least (368.5±32.2). Moisture content varied from 18.7±0.5 in *K. grandifoliola* to 14.8±0.4 in *G. arborea*. Volumetric shrinkage varied from 6.2±1.4 in *G. arborea* to 8.8±1.1 in *K. grandifoliola*. *Gmelina arborea* had the highest concentration of alkaloids (392.2±2.1) while *K. grandifoliola* had the least (217.2±11.7). Flavonoidsranged from 3.2±0.8 in *K. grandifoliola* to 174.7±6.8 in *G. arborea*. Phenols was highest (63.0±0.6) in *T. superba* and least (12.8±0.6) in *T. scleroxylon*. Presence of alkaloids and flavonoids influenced colonisation (R^2=0.86), abscondment (R^2=0.70) and honey yield (R^2=0.72) in *Gmelina arborea* bee hives.

Gmelina arborea and *Triplochiton scleroxylon* were the most preferred wood species for beehive construction in Oyo and Ogun States. High levels of alkaloids and flavonoids in *Gmelina arborea* improved bee colonisation, reduced abscondment, and increased honey production.

Keywords: Honeybee hives, Hive colonisation, Bees abscondment, Yield of honey.

Word Count: 500

CERTIFICATION

I certify that this work was carried out by Adebukola Abeke SherifatAKINLADE under my supervision in the Department of Forest Production and Products, Faculty of Renewable Natural Resources, University of Ibadan, Ibadan, Nigeria.

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Supervisor Date

O. Y. OGUNSANWO

B. Sc., M.Sc., PhD, (Ibadan)

Professor of Wood Utilisation

Department of Forest Production and Products

Faculty of Renewable Natural Resources

University of Ibadan, Nigeria

DEDICATION

This project work is dedicated to Almighty Allah who through the period of this work stood by me, even when all hope seems lost. He was there from the beginning to the very end. This great God through His immense love and mercy has added another feather to my cap, giving me the grace to complete this work even in the face of adversity, All glory and honor belong to Him.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The most well known and utilized products from honeybees is honey. Honey is a sweet and viscous fluid produced by honeybees from the nectar of flowers. Nectar is a thin, easily spoiled sweet liquid that is changed (ripened) by the honeybee to a stable, dense and high-eneergy food. According to Codex Alimentarius Standardization: "honey is the natural sweet substance produced by honeybees from the nectar of plants or from secretions of living parts of plants or excretions of plant sucking insects on the living parts of plants, which the bees collect, transform by combing with specific substances of their own, deposit, dehydrate, store and leave in the honeycomb to ripen and mature" (CAC, 2018).

Honey has been used by humans since ancient times as both a dietary source and sweetner, and until recent times it was also highly regarded as a traditional medicinal treatment for many ailments (Jenkins, 2009). Honey has been extensively used as a topical therapeutic agent in clinical trials on abscesses, ulcers and burns (Jenkins, 2009). A range of positive benefits have been suggested when used to treat these conditions, including reduction of inflammation, pain reduction, reduction of odour, debridement of necrotic tissue (Rao, Krishnan, Salleh, and Gan, 2016).

Honey is sold and consumed around the world. It is consumed raw (unprocessed) as well as used as an ingredient in food, cosmetics, natural medicine and as a source of sugar for making wine or beer. Honey is a barter commodity, cash crop and export crop. Honey exports contribute significantly to the agricultural economy of many developing nations. Most developing countries are capable of exporting honey as long as national production exceeds local requirements (FAO, 2003). Honey can be consumed as soon as it is harvested from the hive (or stored for later use) or it can be used to make a variety or value- added food products such as deserts, dressings and mead. Honey can also be used as an ingredient in other value-added products such as

cosmetics and health supplements. Other harvestable products derived from honeybee include:- pollen, wax, propolis, royal jelly and venom (Tsegay, Gebreegiziabher, and Mesfin, 2017) Honey is a natural substance produced by bees and nutritious food of economic importance worldwide. It is composed of sugars, amino acids, proline, minerals,aromatic substance, pigment waxes and grains (Posho Ndola, Malumba, Wathelet, Haubruge, Francis and Nguyen, 2017; Lawal, Lawal and Adekalu, 2009) and contains large amount of glucose but low in sucrose (Lawal, Lawal and Adekalu, 2009). Honey is easily digestible and more palatable which supplies substantial energy with 75 – 85% fructose and glucose.

Honey bees *(Apis mellifera)* are the primary insect pollinators of agricultural crops, including fruits, nuts and vegetables, which have an appropriate annual value of $17 – 18 billion in the whole world (Al Naggar, Codling, Giesy, and Safer, 2018; Root, 2018). California almond production is the most renowned example of the role of honey bee pollination services in the world. Every year, over 60% of the approximately 2.5 million commercially managed honey bee colonies in the United State are transported to the central Valley of California to pollinate the almond crop. Honey bee colonies are important for the pollination of plants in both agricultural and non-agricultural land- scapes (Al Naggar, Codling, Giesy, and Safer, 2018; Root, 2018).

Bee keeping in Nigeria is a long-standing agricultural practice. It has been exercised as a sideline activity by many of the rural farming communities for its honey and beeswax production that contributes to income generation. It also provides job opportunity in the sector. The role it plays in enhancing food security, poverty reduction and food production through pollination of crops has become substantial in recent years. Beekeeping involves the construction of hives from different types of wood available with movable frames separated by spaces for bees to fix their combs on the frames (Langstroth hive). Even thoughthe wooden hives allows for large-scale bee farming, yet, consideration and emphases should be made on preferred wood species to improve the quality of bee honey produced without prejudice to the bee honey and the bee colony.

There is no well-documented evidence that indicates when and where beekeeping practice started in Nigeria. As indicated by Workneh, Puskur, and Karippai (2008) and

Workneh (2011), it has started in the country between 3000 – 3500 BC. From the rural communities' point of view, beekeeping is an inherited tradition and an ideal occupation that contributes for improvement of livelihoods.

Moreover, Aiyeloja and Adedeji (2014) opined that honey bees may prefer certain trees type with specific characteristics such as species, position, size, safety, height, extractive content and colour for nesting site. Some trees exhibit an irritating and repelling characteristic thataffect their association with some members of "economic insects". Behaviours such as swarming, absconding and migration have been largely used in literatures on bees and frequently employed as synonyms, though they mean distinct events. Swarmingrefers tothe reproductive division of a colony, inwhich part of the workers leave with the older queen and the others remain in the nest with the new queen. Abscondingis the abandonment of a nest by the entire Africanized honey bees colony whereas migration means the movement of an Africanized honey bees colony between distinct ecological regions. Behaviours of absconding and migration have been reported for other honeybee species in other parts of the world. But little is known about the reasons for honey bees' preference for different types of tropical tree species in Nigeria. Studies and literatures are still lacking on the effects of seasonal colony management on honeybee colonies performance and honey production.

Wood as a construction material is used by man and animals as habitat. Many species of forest fauna including rodents, birds and various orders of insects use wood as a form of one habitat or the other. For instance, honey bees use various species of wood for habitation as hives all over the world.

More than 25,000 species of bees have been identified around the world. Bees known as honey bees are represented by eight to ten species in the genus Apis, a name from which comes the word for beekeeping (apiculture) and the word for a bee yard (apiary). The species of honey bee commonly found today is *Apis mellifera,* which means honey carrier. This name is not technically correct as the bees carry nectar from flowers, which they then use to produce honey back in the hive. Races of *Apis mellifera* have different physical and behavioural characteristics such as body colour, wing length and susceptibility to disease.

1.2 Statement of Problem

Hive colonisation in honey production is a major factor in determining the success of beekeeping in the world. However, this process could be delayed due to several factors ranging from biochemical to physical. Delayed colonisation, a situation where hives are not colonised for a long period of time could result from use of materials for hive construction among other factors. Certain types of materials are more attractive to bees than others. It has long been noted that traditional hives are more quickly colonised than top-bar or frame hives. Plastic hives and other man-made materials are often unattractive while some types of wood can have a strong smell which is potentially repellent to bees. Scorched wood, where hives have been flamed to remove infection or pests, often seem to have additional interest, perhaps because of the minerals that may become available to scouting bees. According to Adedeji and Aiyeloja, (2014), honey bees have high preference for yellow and white wood cavities. Failure to pay due attention to these factors may lead to high level of delay in hive colonisation.

Apart from delayed colonisation, abscondment of hive has been found to negatively affect honey production. It is the term used when a colony of honey bees leaves its home in search of another. It is not the same as swarming. When a colony swarms, it splits in two parts: one part stays in the old home and one part finds a new home. Swarming is a form of reproduction. When a colony absconds, however, the entire colony leaves together and finds a new home. Absconding is another of those honey bee behaviours that is not completely understood, but we can draw some conclusions based on repeated observations. Absconding can happen atany time of the year, triggered by things such as lack of food, frequent disturbance, loud noises, and overheating, bad odours, presence of parasites, predators and chemicals especially arising from wood extractives which are unique characteristics of each species. Wood has certain odours which may be choking to newly arriving bees as a result of which they leave soon after colonisation. In general, the environmental conditions in the hive become too stressful for the bees. Somehow they sensed they had little chance of surviving in the present circumstances and decided to leave. It is very important therefore to consider very greatly, the materials used in the construction of hive in order to achieve sustainable hive habitation and hence improved productivity in honey production (Akinmulewo, Oladimeji and Abdulsalam, 2017).

Also, colony losses may endanger productivity and overall sustainability of the entire process of honey production if proper management practices are not put in place to protect and sustain established colonies. Monheim, *et al* (2010) reported that many countries have experienced increase in reported cases of colony losses in Europe, USA, South America, Australia, Middle East and Japan. In Nigeria, Oyerinde and Ande (2009) reported the impacts of bee pests on colony establishment in Kwara State in North-Central Nigeria that resulted in 15% decline in honey bee colony. Colony loss thatis also known as abscondment, in some cases is due to some factors that could be manipulated by man. The absconding and migrating behaviours shown by honey bees, along with their defensiveness, have been considered undesirable traits for beekeeping (Magalhaes Freitas, Sousa and Bomfim, 2007). Globally, honey bees are found to be associated with forests and the flowers of forest trees. The trees physically provide shelter for a swarm or bee hive.

According to Adedeji and Aiyeloja, (2014), honey bees have high preference for yellow and white wood cavities. Failure to pay due attention to these factors may lead to high level of delay in hive colonisation. Certain types of materials are more attractive to bees than others. Studies are important to determine such woody plants that are more attractive and encouraging for honey bees management.

This study is therefore aimed at the compsotion of wood types, used in constructing beehives and the effect on sustainable hive habitation for improved honey production. (Akinmulewo, Oladimeji and Abdulsalam, 2017).

1.3 Objectives of the Study

The general objective of this study was to assess wood species preference for bee-hive production with a view to identify potential wood species for sustainable hive habitation for improved honey production.

The Specific Objectives are to:

i. Produce a compendium of wood species used for beehive construction in the study area and identify the commonly used species.
ii. Investigate selected physical and chemical properties of the identified wood species

iii. Assess the influence of wood species on the pattern of colonisation and abscondment of honeybees in the study area

iv. Evaluate the quality and quantity of honey produced across the hives constructed with different wood species.

1.4 Justification for the study

Beekeeping all over the world requires basic understanding of the honey bees' behaviour during the various seasons and during handling and moving, depending on the country and environmental factors. (Morse, 2007; Issa, 1999; Standifer, 2007; Adjare, 1990).

In Nigeria, like other sub-Saharan Africa countries, honeybees are characterized by frequent disturbance-induced absconding in their wooden hives (Spiewok, *et al.* 2006). Early studies showed that absconding in the African bees is mainly attributed to overheating, lack of water, exhaustion of food stores (Spiewok, Neumann and Hepburn, 2006),also, the role of hive beetles and wax moths in absconding have been documented (Neumann, Pettis and Schafer, 2016). Absconding rates reported for African honeybees include 15-100% for South Africa and 31% for French Guyana (Ellis, Hepburn, Delaplane, Neumann and Elzen, 2003). The preservation of beehive parts and the effect of preservatives on bees were studied by Akyol, Yeninar, Sahinler and Guler, 2006). No documented studies exist on the causes of delay of colonisation and high absconding in the bee hives in relation to the tropical wood species preference by the honeybees in Nigeria.

Adedeji and Aiyeloja (2014) reported that, despite the uniqueness in the choice of cavities selection among the diverse timbers and importance of honey bees to our wellbeing, the honey bees have preference for the natural wood species. Likewise, some plant species contain insecticidal and/or insect-repellent substances. A review by Sukumar, (1991) highlighted the potential of plants for use in mosquito control, either as repellents, larvicides, or insecticides. However, irritating and repelling chemical constituents of wood species could be the major factors responsible for the absconding and delay in colonisation, hence, resulting in the decline in honey bee colony production per unit hive. Many suggestions have been proffered by many authors, for instance, Spivak and Reuter (1997) opined that the problem of regular absconding and swarming can be solved and poor colony strength improved through honey bee queen

rearing, while Gidey, *et al* (2012) reported that lack of food, honey bee pests and drought are the main problems that may cause absconding. Yet, absconding and delayed colonisation by honey bees still occur in honey bee keeping.

In Nigeria, there is no detailed study of the effects of wood species repellence nature, on beneficial insects like honey bees. Current literature on the wood species preference does not provide information on vulnerability and resistance shown by the local honeybees and the consequences on the beekeeping activities in Nigeria. Therefore, this study will focus on the observation of woods species preferred by bees among hives, causes of abscondment and delayed colonisation by Africanized honey bees in South-West, Nigeria.

1.5 Scope of the study

This study was carried out in Onifuufu (Iddo LGA), Ogunmakin (Oluyole LGA), Adeaga (Odeda LGA) and Ayetoro (Egbado LGA) Villages, in Oyo and Ogun States and it was limited to five wood species which were used to construct the hives. The wood species are *Gmelina arborea, Cordia Millenii, Triplochiton Scleroxylon, Khaya grandifoliola* and *Terminalia Superba.* The chemical and physical properties of the wood species were examined as well as the influence of the wood species on the quality and quantity of honey production. The chemical constituents of the five selected wood species were also investigated. The physical properties such as Moisture content, Density and Shrinkages were determined.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Evolution of Bees and Bee Keeping

Bees likely evolved from wasp like ancestors, contemporaneously with the angiosperm plants towards the end of cretaceous period, 60 to100 million years ago (Sahle, Enbiyale and Negash, 2018). According to (Tessega, 2009) the present bee fauna probably originated more than 70 million years ago. Currently, eleven families of bees are generally recognized, only some of which are identified by derived traits setting them apart from other bee families. There are about 1000 genus (and sub genus), combined with sub genera, approximately 600 generic groups and an estimated 20,000 living species of bees residing in the world's museums (Sahle, Enbiyale and Negash, 2018).

Bees (Apoidea) are a super family of about 20,000 species, in the order Hymenoptera. The majority of bee species are 'solitary' while the minorities are social (bumble bees and stingless bees), and only a few species of social bees, are kept in hives by beekeepers. There are three families of social bees, which produce honey. These are: the Bombidae, Meliponidae and Apidae (Tessega, 2009). The Bombidae are found mainly in temperate climates. Their nests are very small, often in the ground and are of no commercial importance except as pollinators of certain plants. The Meliponidae, or stingless bees, occur throughout the tropical regions of the world. Their nesting places may be holes in the ground, in hollow trees or small cavities in walls and on the underside of branches. The family Apidae, to which the honeybee belongs, is indigenous only to Europe, Africa and Asia (Sahle et al 2018).

A honeybee found in East Africa was reported from the upper Pleistocene period, 100, 000 years ago. This bee could not be differentiated from the contemporary African honeybee species (Tessega, 2009).

Beekeeping, which is today practiced over a greater area of the earth's surface than perhaps any other single branch of agriculture, passed through different stages of development: honey hunting, traditional (forest and backyard) and improved (movable-frame and movable top-bar) methods of beekeeping.

It is likely that man hunted for wild nests of bees and looked for their honey during the whole of his existence. Early man probably took honey from bees' nests wherever he found them, and the collection of honey from wild nests continued except in some regions where it has been entirely superseded by beekeeping (Tessega 2009). There are many references to honey in ancient records and literature, but most of them gave no clue as to whether the honey was obtained by honey hunting or beekeeping. Wherever writing was known, honey was mentioned so many times in the Holy book of the people, and it often held a place of honor in their rights (Sahle et al, 2018).

The earliest known evidence of honey hunting scenes was a painting made in a rock shelter in the mountains of eastern Spain in Mesolithic times, probably dated to about 5000BC (Sahle et al, 2018). Africa has many rock paintings about honey hunting than any other continent and some of the countries, which can be mentioned, are South Africa (Natal), Zimbabwe, Morocco, Libya and Tanzania (Sahle et al, 2018).

Honey hunting has been a very common practice even up to present generation in many parts of Africa, including Ethiopia. In southwestern parts of Ethiopia, some households entirely depend on honey hunting and forest beekeeping for their entire livelihood. Honey hunting is also common in pastoral communities in which beekeeping seem impossible.

Beekeeping properly started when man learned to safeguard the future of the colonies of bees he found in hollow tree trucks, rock crevices or elsewhere, by a certain amount of care and supervision. Tessega (2009) reported that by 2500 BC, before forest beekeeping is known to have existed, fully fledged beekeeping was being practiced in ancient Egypt and the earliest written records that relate to the keeping of bees in hives are from about 1500 BC. Generally, the earliest known evidence of beekeeping has been found in the Africa continent (Sahle et al, 2018).

Beekeeping up to 1500 AD continued in the traditional form using primitive hives. Of all the regions under consideration, tropical Africa has the oldest tradition of beekeeping and still with primitive hives (Sahle et al, 2018). Between 1650 and 1850 AD many hives with top-bars and frames were invented, but after these two centuries of effort there was still failure on the fundamental point: whatever bars or frames were used, the bees attached their comb to the walls of the hive as well, and the combs could, therefore, only be removed from the hive by cutting them out. Lorenzo Lorraine Langstroth made the step, which changed this, in 1851 when he discovered practical movable-frame hives with an appropriate 'bee-space'. The pattern of modern beekeeping was thus established between 1850 and 1900 AD. Different equipments were invented in this period, but Langstroth is advance in 1851 remains the basic principle of the box hive, and thus of our beekeeping today (Sahle et al, 2018).

2.2 Biological family and Species of Honeybees

Since the late 1700s, about 9 species of honeybees have been recognized (Tessega, 2009). These are: *Apis andreniformis, Apis cerana, Apis cerana indica, Apis dorsata, Apis dorsata binghami, Apis florea, Apis laboriosa, Apis mellifera* and *Apis vechti*. Among these, the following are the major honeybee species and are of world economic importance: *Apis cerana/indica, Apis dorsata, Apis florea* and *Apis mellifera*. Race in honeybees is a result of natural selection and honeybees have been adapted to different geographical areas of the world for many years without the interference of mankind. In so doing, there has been an environmental effect on the anatomy and physiology of honeybees leading to differentiation.

African and European honeybees, even though were from the same species, are differing in behavior, production and on some morphological variables of importance. Hence, quite a large number of subspecies (races) of honeybees are found in the world today. Tessega (2009) reported the presence of 23 distinct geographical races using multivariate analysis of the morphometric characteristics of honeybees. In Africa alone, more than 16 subspecies or races are residing in different ecological places.

Bees that produce enough honey sworth harvesting belong to the two sub families of the family *Apidae*: *Apinae* (honeybees) and *Meliponinae* (stingless bees). *Apinae* has

only one genus, *Apis*, and about nine species of which the *Apis mellifera* species is of much greater economic importance than any others.

Apis mellifera ('honey- making bee') is one of the most successful species in animal kingdom. It became more adapted to wide range of environmental condition to a greater extent: one and the same species is able to survive in semi desert tropical regions as well as in cold-temperate zones (Tessega 2009). The races and strains of *Apis mellifera* are overriding world importance in beekeeping, and are the basis of world's beekeeping industry. These bees are native to Africa and Europe. They have also been introduced in to almost the whole of the New World (the Americans, Australia, New Zealand and Pacific Islands) since 1500 where there were no native honeybees.. European *Apis mellifera* is the bee first studied, and it still receives by far the most attention.

Apis dorsata and *Apis florea* are confined to tropical Asia, and each species builds a single comb in the open, unprotected or semi-sheltered area. *Apis cerana* and *Apis mellifera* live in the Old World tropics, but during evolutionary times they succeeded in spreading in to the north temperate zone of the Old World. Each builds a nest in a cavity, consisting a number of parallel vertical combs, usually up to about ten; thus, they can be managed for honey production and for crop pollination.

Apis mellifera is now the most productive and widely distributed in almost all places of the world. Tropical subspecies of *Apis mellifera* are smaller than temperate zone subspecies, and they have a more slender abdomen. They are generally less amenable to handling and management, swarm readily; also, the whole colony may abscond as a result of damage and disturbance of their nest or shortage of food. Moreover, the bees are easily alerted to sting and this characteristic allows their survival in the African tropics where they were liable to be attacked by many 'enemies' (Tessega, 2009).

Nowadays, these bees are kept in hives in almost every country of the world and beekeepers have to operate in widely different conditions. Adjare (1990) noted that the honeybee is well distributed over the globe except in the severe cold of the Polar Regions.

2.3 Types of beehives

A bee hive is an enclosed structure in which some honey bee species live and raise their young. Natural bee hives are naturally occurring structures occupied by honey bee colonies, such as hollowed trees while domesticated honey bees live in manmade beehives, often in an apiary which includes;

Top bar Hives

The top-bar or Kenya-hives were developed as a lower-cost alternative to the standard Langstroth hives and equipment. They are popular, owing to their simplicity and low cost, in developing countries. Top-bar hives have movable comb and make use of the concept of bee space. The top-bar hive is so named because the bees draw their comb from a top bar, suspended across the top of a cavity, and not inside a full rectangular frame with sides and a bottom bar. The beekeeper does not provide foundation wax (or provides only a small starter piece of foundation) for the bees to build from. The bees build the comb so it hangs down from the top bar. This is in keeping with the way bees build wax in a natural cavity. There is some belief that the use of natural wax in a top-bar hive supports the bees' natural systems in ways that improve their health.

The hive body of a common style of top-bar hive (Table 3.1) is often shaped as an inverted trapezoid. This is in order to reduce the tendency of bees to attach the comb (Table 3.2) to the hive-body walls, though this reasoning has become less popular recently. It may be more likely that the trapezoid shape helps to improve the ratio of the weight of the comb to the amount of attachment at the bar and helps to lessen the likelihood of heavy combs detaching from the top bar when being handled or harvested. Unlike the Langstroth design, this style of top-bar hive is expanded horizontally, not vertically. The top-bar design is a single, much longer box, with the bars hanging in parallel.

Unlike the Langstroth hive, the honey is usually not extracted by centrifuging because a top-bar frame does not have reinforced foundation or a full frame. Because the bees have to rebuild their comb after honey is harvested, a top-bar hive yields a beeswax harvest in addition to honey. However, like the Langstroth hive, the bees can be induced to store the honey separately from the areas where they are raising the brood.

For this reason bees are less likely to be killed when harvesting from a top-bar hive than when harvesting from a skep or other traditional hive design.

Langsthroth beehives

Langstroth hives make use of bee space so that frames are neither glued together nor filled with *burr comb*–comb joining adjacent frames. Langstroth hives use standardized sizes of hive bodies (rectangular boxes without tops or bottoms placed one on top of another) and internal frames to ensure that parts are interchangeable and that the frames will remain relatively easy to remove, inspect, and replace without killing the bees. Langstroth hive bodies are rectangular in shape. Inside the boxes, frames are hung in parallel. The minimum size of the hive is dependent on outside air temperature and potential food sources in the winter months. The colder the winter, the larger the hive and food stores need to be. In regions with severe winter weather, a basketball-shaped cluster of bees typically survives in a "double-deep" box.

Langstroth frames are thin rectangular structures made of wood or plastic and have a wax or plastic foundation on which the bees draw out the comb. The frames hold the beeswax and honeycomb formed by the bees. Ten frames side to side will fill the hive body and leave the right amount of bee space between each frame and between the end frames and the hive body. Langstroth frames are often reinforced with wire, making it possible to extract honey in centrifuges to spin the honey out of the comb. As a result, the empty frames and comb can be returned to the beehive for use in the next season.

2.4 Honey

Honey, which is a substance produced by bees (Appendix 6b) from pollen grains of trees has found its use in several aspects of our everyday life ranging from beauty purposes to being used as a sweetener in food substances and most importantly in health treatment. Basically, honey could be classified into three main types and these are

1. Man-made honey
2. Self-bred honey
3. Wild honey (especially South-West of Nigeria)

Man-made honey is made from some compounds which may be table sugar or other substances that have high sugar contents. This class of honeys has been found to be dangerous to health. Self-bred honeys on the other hand is honey gotten from bees

which are bred in a confined (intensive) environment while Wild honey on the other hand is honey produced by bees living in their natural habitat which in most cases is in the forest. This honey has been proven scientifically to be very beneficial to health with a high emphasis placed on honey gotten in tropical areas such as south-west of Nigeria.

Pure natural honey contains enzymes that are considered essential for good health and also contains natural minerals needed by the body. It is the most assimilated carbohydrate compound for the body, it is also an effective aliment to generate heat, create and replace energy, and furthermore, to form certain tissues. Moreover honey supplies the organism with substances for the formation of enzymes and other biological ferments to promote oxidation. Listed below are some of the countless functions and importance of honey (Flottum, 2010). Honey can be used as an antimicrobial i.e. can be used to treat cuts, scrapes and burns as well as to prevent scarring) due to its high sugar content, low pH and the presence of organic acids.

Honey is used as a hair and facial treatment because it attracts and retains moisture. Honey contains the vitamins B6, thiamin, niacin, riboflavin and pantothenic acid. Honey is rich in minerals such as calcium, copper, iron, magnesium, manganese, phosphorous, potassium, sodium and zinc. Honey contains antioxidants such as chrysin, pinobanskin, vitamin C, and catalase. Honey is a great source of energy due to its high content of carbohydrates. Honey with higher water content has strong antioxidant potential. The antioxidants found in honey include pinocembrin, pinobanksin, chrysin and galangin (Gibbon, 2001). Using honey in baked foods will keep them moist for a longer period of time. Honey never goes bad since It is slightly acidic and, therefore, not conducive for bacterial growth.

The composition and quality of honey vary, depending on the climatic region, whether wet or dry, the environmental temperature, the type of plant used to produce it, the honey bee species, the sugar composition, the treatment of honey during extraction, processing and subsequent storage conditions (Alvarez-Suarez, 2010; Amril and Ladjama, 2013). Honey comes in a range of colours including white, amber, red, brown and almost black (Eleazu *et al.,* 2012). Its flavor and texture also vary with the flower nectar from which it was made. The most commonly available honey is made from clover, alfalfa, heather and acacia flowers (Alvarez-Suarez, 2010). They are

available as raw or processed honey. The latter is usually pasteurized, clarified, or filtered and at times fortified. Raw honey is of the highest organic quality and is regarded as 100% pure.

2.4.1 Honey Bee Colony

A healthy honey bee colony has three distinct types of individuals: a queen, workers, and drones. Each type of bee has a distinct role in the colony. Collectively, they make up the members of a honey bee colony (Flottum, 2010). The queen is critical to the survival of the colony. Usually, she is the only actively reproductive female and lays all the eggs in the colony. Normally, only one queen is present in each colony, and she is the mother of all the individuals in that colony. The workers also are female but have undeveloped ovaries, so they normally do not lay eggs. They perform all of the work in the colony, including caring for the brood, building the comb, tending to the queen, gathering resources (nectar, pollen, resins, water), and defending the hive (Collison *et al.,*2004). The tasks workers perform change as they age and are influenced by the particular needs of the colony at a given time. A colony may contain 20,000 to 60,000 workers, depending on its age and the time of year. Male honey bees are known as drones. Their only task is to mate with virgin queens, usually from colonies other than their own.

They are larger than workers and are identified easily by their large, contiguous (touching each other) eyes. Mature drones leave colonies in the early afternoon and fly to drone congregation areas found 40 feet above the ground. Here drones in flight wait for a virgin queen on a mating flight. If successful mating takes place, the drone dies immediately after mating. Colonies may contain none, a few, or several hundred drones, depending on the strength of the colony and the time of year (Caron, 1999). In the fall or after an abrupt end to a honey flow, workers force drones out of the colony. They may also remove any developing drone brood from the colony, which can pile up at the colony entrance. Honey bees develop through a process called complete metamorphosis. Like butterflies, bees begin life as an egg, and then enter the larvae stage before spinning a cocoon, pupating, and later emerging as adult bees. Unlike butterflies, bees complete all these stages in one place, a single cell of the comb (Collison *et al, 2004*).

This study therefore focuses on the wood species suitable for beehive construction with consideration for reliability and longevity in service.

2.4.2 Honey bee Colonisation and Abscondment

Honey bee Colonisation refers to **the process of bringing honeybees** into an artificial hive made for them by attracting a swarm, colony division or queen bee breeding. Beekeepers installs bee hives in areas where the beekeeping raw materials abound and where the bees like to live to guarantee high colonisation. Previous researchers noted that hive colonisation by honey bees in Africa are influenced by hive types (Ande *et al*., 2008), tree shade management (Kugonza *et al*., 2009), polythene and lime applications to top bars (Babarinde *et al*., 2010), apiary management (Okwee-Acai *et al*., 2010), hive dimension and entrance (Babarinde *et al*., 2012) and hive wood colours (Adedeji and Aiyeloja, 2014).

There are different methods of hive colonisation by honey bees, apart from self colonisation which is the widely known method of colonisation; Adjare (1990), highlighted some other methods:

i. Self-colonisation: The beekeeper installs the baited beehive and waits until a swarm of bees comes to colonise the hive. The time required for colonisation after bee hive installation varies, hives sited near the forest flowering plants will be colonised rapidly while hives sited close to the residential areas takes a longer time to be colonised.

ii. Catching a swarm (Method I): As noted above, not all hives are self colonised. Bee keeping is more developed in places like Europe, Australia, America and some northern and southern African countries when compared to tropical African Nations. Therefore, when setting up or expanding an apiary, beekeepers purchase package bees or buy nucleus or established hives. Moreso, another method of catching a swarm is

iii. Removing wild bees from their nest: This is usually carried out late in the evening after 6pm, the beekeeper wears protective cloths and other necessary materials such as a good smoker, an empty bee hive, a container to carry honey bee and tools like hammer, saw and chisel. The smoker is filled with fuel and puffed through the bees' gateway into the nest for five minutes; this makes the bees to rush into the nest and gorge themselves full of honey which eventually makes them too heavy and drowsy to move. The nest is opened using

appropriate tools and the honey comb is removed into a container which makes the honey bee swarm round the broad combs. The broad combs and the bees are then removed together and moved into a new hive at least 3km away from where they are collected.

Absconding of honey bee refers to the movement of an entire colony from a hive; it's a process that leaves no bee behind in the original colony (Winston, 1992). It differs from swarming in that swarming bees are splitting of a hive into two parts, half of the bees Generally, African honey bee are known to frequently respond to unfavorable periods by undergoing seasonal absconding or migration, which consists of abandoning a nest site and moving into an area of greater resource abundance (Fletcher, 1978; Winston *et al.*, 1983; Schneider, 1990). When preparing to abscond, the honey bee makes preparation in advance of the moving day. The Queen ceases to lay eggs and slims down in preparation for flying, foraging stops, scouts begin searching for a new and suitable new home and the honey stores are also used up.

There are two types of absconding; disturbance-induced (unplanned) absconding and resources-induced (planned) absconding.

i. Disturbance-induced absconding is as a result of predation or invasion of colony by pest, fire, drought,inability to regulate temperature due to cold or excessive sunlight, rain entering the nest, and beekeeping manipulations.**(**Fletcher, D.J.C. 1978).
ii. Resource-induced absconding occurs due to lack of nectar, pollen or water and this occurs majorly during the dearth period found in the tropical region **(Griffiths 1976)**. This type of absconding is seasonal and unlike the disturbance-induced absconding the colonies prepare for it like a month ahead of their movement

2.5 Effect of Bee Hive on Colonisation and Abscondment

According to (Croft, 1990) beekeeping is the maintenance of honey bee colonies, commonly in hives, by humans. There are many types of bee hives commonly used by bee keepers throughout the world for honey production. They are all categorized as modern and traditional bee hives. (Croft, 1990) Stated that beekeeping is the maintenance of honey bee colonies, commonly in hives, by humans. Low-technology hives have been developed as a way of obtaining the advantages of movable frame

hives (no need to break combs, standardization, manageability, efficient honey harvest) without the disadvantage of high cost manufacture. The container for the hive may, like traditional hives, be constructed from whatever materials are locally available. Low-technology hives can be kept near home, and can, if constructed and transported with care, be moved between crops as they flower successively (Global Development Solutions, 2009). For modern hives the combs can be lifted from the hive and then replaced and this allows the beekeeper to examine the condition of the colony without harming it. Honeycombs can also be removed from the hive for harvesting without disturbing combs containing brood. The colony is therefore not harmed and the bees can continue gathering honey to replace that which has been harvestedwhich ensures good quality honey can be harvested, free of contaminating pollen or brood (Logan, 1990).

Honey bees are insects of the super family Apoidea in the order Hymenoptera (Parker, 1981). Economically important species of honey bees include the *Apis cerana, Apis dorsata* and *Apis mellifera* (Roubik, 1989; Howpage, 1991). But, the most widely spread economic species of the honey bees is the *Apis mellifera*, which is native to Europe, Middle East and Africa with about 25 distinctive races (ERLS, 1995; Segeren, 1997). Bee colonies are usually initiated by swarming with a prospective queen leading the way in most developing bee management settings, while on the advanced note colonies can be obtained from a queen rearing program. A colony consists of three castes i.e., infertile female (workers), male (drones) and a fertile female (queen) (Johansson, 1980). The basic principles of beekeeping are simulation of what is evident in the bee colony in the wild (Karlsson, 1990) with the ultimate goal of sustaining the bee colony and easing harvesting process. However, the improved interest in beekeeping as a result of the growing demand for bee products and services made the few natural wild colonies inadequate. Hence, the advent of special artificial hollows in the form of bee hives (Adjare, 1990) presently engaged in the practice world over. Bee hive construction varies from one area to the other (Olagunju, 2000). The traditional bee hives was initiated in an attempt to utilize the cheap and plentiful local materials for hive construction. In Nigeria, the common traditional hive includes: gourds, clay pot, raffia basket, rolled up straw and hollow trunks (ERLS, 1995). Modern bee hives on the other hand adopt the principle of having a box-like enclosure with removable top or frames, which facilitate routing inspection of the established

colonies. The common modern beehives in Nigeria includes: Kenyan top bar, Langstroth and East African long transitional top bar hives (Olagunju, 2000).

The bee hives used range from traditional to modern. The traditional/fixed comb bee hives are of various types depending on the location with locally available materials used for hive construction ranging from bamboo, palm tree logs, twigs to sticks. Two types of modern hives made from timber in use are: Kenya Top bar hive (KTB) and the Langstroth hive. The local bee hive usage is higher than modern bee hive usage and the local hives tend to be more colonized than modern hives (Kugonza and Nabakabya, 2008; Ndyomugyenyi *et al*., 2015).

Morse, 1990 mentioned that hives in cellar wintering, a technique that was often used at the turn of the past century. While only one of the variables of the equation, food consumption, is measured, the hive temperature increased, when they are moved to a relatively warmer place. When the hives are outside they consume 22.3 kilograms of honey during the season, but when they are placed in a cellar they only consume 6.8 to 13.2 kilograms. Starks *et. al*., 2000 observed that honeybees raise the temperature of the brood area regularly to increase the brood activities and protect themselves against predators. They have also stated that when *Ascosphaera apis* which is the pathogen of chalk brood contaminates to the colony at the temperatures below 30 ºC, honeybees realize this and raise the temperature before the broods get sick. There have been many attempts to reduce the loss of honey bee colonies in winter, by improving the conditions of temperature inside the bee colonies, such as:(Furgala, and McCutcheon, 1992, Abrol, 2001,Wineman *et. al.,* 2003; Dodologlu, *et. al.,* 2004; Erdogan, *et al*., 2009; Morse, 1999) recommended keeping bee colonies in the Northern U.S. during the winter in dark-painted hives and exposed to full sunlight, but provided no experimental data to indicate any beneficial effect of such a treatment. There are little researches about warming of beehives under Egypt condition. Bees or adult population was estimated in the rate of 2000 adult bees, which can cover a comb from both sides (Hauser and Lensky, 1994).

Morse and Hooper (1986), reported in a follow up study in U.S.A, that bee swarms were offered a variety of bait hives of various designs and shapes to determine if bees could make choices. The results show that the nest preferred by honeybee is quite different from that given by man. One conclusion from these studies is that honeybees

have wide range of adaptability. They added that, in their study 75% of the trees in which bees were found and observed nesting were alive, and the mean volume was a 45 litres. In tests in which bees were offered boxes of various sizes it was noted that the bees preferred nests near this value.

Hive is the name given to any container in which bees are kept by the beekeeper (Morse and Hooper 1986). Practically all the hive types used by traditional beekeepers are hung on tree branches whether by ropes or wires or placed between the branches. Morse and Hooper (1986) reported that all the data on honeybee biology suggest it is important to elevate colonies as much as convenient. They added that in African tribes that have been keeping bees for centuries, hang their nest boxes 15 or more feet above the ground. They stated that in a follow up studies in the eastern United State in which bees were offered nests 3 and 15 meters above the ground the bees preferred the latter.

Originally the hive was made of any suitable material easily available in the area, and therefore varied quite considerably in size and shape. Morse and Hooper (1986) reported that different hive types had been used in different parts of the world, as pottery or sun-baked pipes in Egypt and other Arab countries, horizontal hives made from planks of wood and from hollowed-out logs in northern Europe. In Britain and Western Europe hive were constructed in basketwork plastered or cloomed, with a mixture of mud and cow dung, beside flat-tapped skeps and wooden boxes, open topped skeps, were used.

El Sarrag (1977) mentioned that the natives in the Sudan use a number of different hives, but all are hollowed and long for example, log hives, woven and clay pots. In 1918 trials were made to improve the hives used by the natives in Sudan. King (1920) recommended Khartoum hive, but this hive as well as the native hive proved unsatisfactory since swarms of honeybees are not always attracted to inter them. Moreover, they were clumsy and liable to break. Their material would not withstand the weather and became soft and rotten after one year. The queen excluder devised in Khartoum hive was not available to the natives (El Sarrag, 1977).

As an alternative to Khartoum hive, King recommended Omdurman hive. In 1932, this hive proved to be satisfactory, because it withstand the weather, could be used for several years, besides it enables the owner to collect honey several times (El Sarrag,

1977). Since 1936 different types of hives were used in Sudan. In 1961 the Langstroth standard hive was introduced by Prof. Khalifa to the faculty of Agriculture, University of Khartoum for educational purposes. This hive which is getting popular today was successful.

Fletcher (1975) found that for tropical bees there are a number of absconding causative factors. These include disturbance by predators or excessive manipulation, wax moth infestation and heavy wasp or bird predation at the nest entrance. Butler (1967) reported that although absconding is rare in temperate zone races of honeybee, it is relatively common in tropical honeybees. Smith (1960), Butler (1967) and Fletcher (1973) showed that there are two basic types of absconding.

a) Disturbance caused by predators, pests, manipulation by beekeepers, fire, inferior nest site etc.
b) Seasonal absconding thought to be induced by dearth of sources or other seasonal factors such as high winds, rainfall, or high temperature.

Wok A I. (2018) studied absconding and its relation to brood rearing in *A. mellifera adansonii*. He found that absconding colonies usually left behind a few hundred eggs, but very little brood. Winston (1987) studied the absconding behaviour of Africanized honeybee in South America. He stated that colonies that had swarmed just prior to the absconding season and that had low numbers of workers particularly young workers had a relatively high probability of absconding during the wet season.

The chief factors responsible for absconding were insufficiency of food in the brood nest to tide over unfavourable periods, invasion by ants, wasps or wax moth, frequent disturbance, desertion of new site, incorrect location of colonies and persistent swarming. Smith (1960) reported that the most common causes of absconding are lack of water, exhaustion of food stores, over heating and continuous pest attack. He also stated that an established colony of bees, whether *mellifera, adansonii* or *indica* will not abscond if they can get water, have plenty of food stores, and secure from attack by pests, are in strong healthy condition and in a well-ventilated hive shaded from the full heat of the midday and afternoon sun.

2.6 Factors influencing honeybee populace

Many factors may account for the declines of honey bees in the US and Europe. In all likelihood, no one factor on its own can account for all losses or gains over a given time period. Many factors can occur simultaneously and some influence one another. The remainder of this article is a general review of some important factors thought to impact colony numbers and a discussion of their likely impact on honey bee populations. With few exceptions it is nearly impossible to determine the cause of a honey bee colony death after the fact. If a colony dies during winter, a considerable amount of time may pass before it is noticed by the beekeeper, and clues to the cause are usually lost. To definitively determine the cause or causes of mortality in colonies a priori sampling and analysis of a representative portion of colonies is needed. Such longitudinal studies enable causes of mortality to be inferred and the relative risk of risk factors (on their own or in combination) to be calculated.

Several national colony monitoring programs have been initiated. One of the first and most comprehensive of these programs was the German Honey Bee Monitoring Program, where about 1200 colonies are continuously followed over a period of several years. Colony strength and health status are regularly assessed, and samples are taken and checked for disease and parasite loads. Although laborious and cost-intensive, this project has proven useful, because it generates reliable data enabling relationships between risk factors and colony death to be determined.

Diseases and parasites

There are many honey bee diseases (bacterial, fungal, viral, microsporidial), parasites (mites), predators (bears, birds, humans), and pests (beetles, moths) that can adversely affect managed honey bee productivity and survival (Morse and Flottum, 1997). A comprehensive discussion of the most important diseases and parasites of bees is provided in subsequent chapters of this issue. Here, we provide a brief discussion of a few of the most significant diseases and parasites, specifically those that may have and/or continue to play a significant role in changing honey bee populations.

Varroa destructor

The parasitic mite, V. destructor, formerly known as Varroa jacobsoni, is the most detrimental honey bee parasite in the world today. This mite moved from its original host, the Asian bee *Apis cerana*, to *A. mellifera* colonies imported to Asia. On their new host, varroa mites have spread to nearly all continents where *A. mellifera* are kept. Today, it can safely be assumed that all honey bee colonies within the mite's range harbor varroa mites. As a consequence of mite infestation, dramatic colony losses have repeatedly occurred in affected countries (Finley *et al*., 1996; Martin *et al.*, 1998). Female varroa mites feed on adult bees, but depend on bee brood for reproduction. Both the adult female and her offspring feed on pupae, where they can cause damage by ingestion of hemolymph, resulting in severe nutritional deficits for the developing bee (Duay *et al*., 2003). In addition, alteration of the bee's physiology and secondary infections contribute to the damage (Amdam *et al*., 2004). The level of infestation of varroa mites that cause colony damage appears to have decreased over time. In the early 1980s, in Europe, a bee colony could harbor several thousand mites without dramatic symptoms (Boecking and Genersch, 2008). Today, however, a fall infestation rate of 10%, corresponding to about one thousand mites in a colony of 10,000 bees, is considered to be a critical threshold for winter survival of the colony.

Interactions between viruses and mites

Colonies with varroa mite infestations that are not effectively controlled quickly develop disease symptoms and, if left untreated, inevitably will collapse. The damage is manifested by reduced colony development, the presence of malnourished, deformed, and underweight bees, or crawling bees that are unable to fly or have crippled wings. Brood in infested colonies may also have a condition termed ‘‘parasitic mite syndrome (PMS)” (Shimanuki *et al*., 1994). Many of these symptoms are thought to be caused by viruses associated with varroa mite infestations (Hung et al., 1996). Varroa mites can vector several viruses, most of which were present in honey bees before varroa invasion (Bailey and Ball, 1991), but remained covert, symptomless infections (Bowen-Walker *et al*., 1999; Yue and Genersch, 2005). For several of the about 18 known honey bee viruses (Chen and Siede, 2007) interactions with V. destructor are known, either through virus transmission by the mite, or through other means of action. For instance, pupae parasitized by varroa mites may suffer from an

impaired immune system and seem to be more susceptible to virus infections (Yang and Cox-Foster, 2005). The distribution of many viruses appears to match the distribution of the varroa mite, but, for some viruses, there also appear to be regional differences (Ellis and Munn, 2005). Results from the German Bee Monitoring Program over 4 years indicate a clear and highly significant correlation between colony winter mortality, fall mite infestation rates, and both Deformed wing virus (DWV) and Acute bee paralysis virus (ABPV) loads. Colonies with a high mite load in October had both more viruses and a significantly higher risk of mortality in the winter (Anonymous, 2008). Although DWV can be transmitted directly from bee to bee, expression of clinical symptoms, such as crippled wings or a shortened abdomen, only occurs after mite-to-pupa transmission of virus particles (Bowen-Walker *et al*., 1999; Yue and Genersch, 2005; Yue *et al*., 2006, 2007; Tentcheva *et al*., 2006). DWV has repeatedly been shown not only to be efficiently transmitted by the mite, but also to replicate in mite tissues.. The biology of DWV and in particular the interactions between DWV and V. destructor have recently been described in detail (de Miranda and Genersch, 2010). Like DWV, ABPV was known as a honey bee virus before the arrival of varroa mites, although it usually did not cause clinical symptoms or lead to colony death (Bailey and Gibbs, 1964).

Nevertheless, the prevalence of ABPV in Europe was shown to increase after the arrival of the mite (Allen and Ball, 1996), which had been identified as an efficient transmission vector (Ball, 1983). While there is currently no experimental evidence for viral replication of ABPV in varroa mites, it has been confirmed that infections with this virus are more deadly in combination with the mites. A recent study found a strong correlation between high fall mite loads, viral loads and increased winter mortality (Siede *et al.*, 2008). In contrast, all colonies with viral infections, but without detectable mite levels in the fall, survived (Siede *et al*., 2008). The highly virulent Kashmir bee virus (KBV) has been found to be present in countries (e.g. Australia) still free of varroa mites (Bailey *et al*., 1979); however, interactions between the virus and the mite have been established. KBV can be transmitted by varroa mites, but there is still no proof of viral replication in mite tissues (Chen *et al*., 2004; Shen *et al*., 2005). The presence of mites clearly elevates viral titers in infected bee pupae suggesting that increased viral replication in the bee is correlated with parasitization although the exact mechanism remains elusive (Shen *et al*., 2005). It has been

hypothesized that immunosuppression of the bee by protein components of the mite saliva facilitates virus replication (Shen *et al.*, 2005). KBV has been shown to be prevalent in the U.S, but is unevenly distributed in Europe. It was found in France, but appears to be mostly absent in Germany (Siede and Büchler, 2004).

The Israeli acute paralysis virus (IAPV) has received considerable scientific interest as a potential causative agent for Colony Collapse Disorder (CCD), because its presence was correlated to an increased risk for colony collapse (Cox-Foster *et al.*, 2007). Because IAPV has been detected in samples that predate CCD (Chen and Evans, 2007), its role in CCD is likely secondary (Cox-Foster and van Engelsdorp, 2009). An interaction between IAPV and varroa mites has not been demonstrated to date. However, recent data suggest that ABPV, KBV, and IAPV may not represent clearly separated, different species, but rather form a complex of closely related species. Due to their close genetic relationship, especially KBV and IAPV sequences have been frequently misclassified in the literature and the public sequence databases (de Miranda *et al.*, 2010). The similarity of these three viruses has to be considered when evaluating their impact on colony health.

2.6.1 Enviromental Factors and Honey Bee Behaviour

Environmental weather determines the intensity of daily activities and foraging patterns in honeybee. Their level of activities and population size vary with different seasons (Kovac and Stabentheiner, 2011, Tirado *et al*, 2013). Temperature and relative humidity determine the activities of honey bees including their feeding behavior. Honey bees maintain temperature and relative humidity inside their hives within narrow limits such as the maintenance of broods on the combs of a steady body temperature range of 33^0C to 36^0C (kleinhenz *et al* 2003) constant temperature range is essential for the growth and development of broods in the colony. (Tanz *et. al,* 2013) reported that any change in temperature from 30^0C – 36^0C may be detrimental to the development of the broods. A change in temperature will make the worker bees to engage in behavioural and physiological activities to either warm up or cool the brood as situation demands. In such a situation, honey bees use metabolic heat to regulate the temperature of their immediate environment.The broods are the most affected by

change in the hive temperature, hence worker bees take great care to maintain the temperature in the brood chamber (Kleinhenz *et al*, 2003).

Temperature and relative humidity had significant influence on the collection of pollen, nectar and pollen loads. Increased as relative humidity rose while high temperature showed a strong negative influence on the number of honey bees that collected the pollen. Honey bees are more active in dry season than in wet seasons. When bees are more restricted within the hives forming clusters to generate more heat to survive the wet season (Fasasi, 2016), hence high yield output in dry season than in wet season. The beehives in south west Nigeria, was observed to attain their peak production between November and April within dry season when temperature is between 30.5^0c to 32.1^0c and relative humidity is between 58.2% to 66.3%. The bees are docile in wet season when temperature is between 26.6^0c to 30.2^0C and relative humidity is between 62.2% to 76.36%.

2.7 Honey production and Marketing

World production of honey during the 1990s was in excess of 1.2 million metric tons (MT) per year. Bee wax production was more than 50,000 MT per year. World demand for these products is substantially in excess of these amounts and is likely to increase even further. FAO (2005) data indicated that world trade in honey during the 1990s was more than 300,000 MT per annum with Western Europe and the United States in particular being major importers at an average price of about US $1500 per MT. World trade in beewax was about 10,000 MT per annum where Western Europe accounted for about one half of total imports with the world price average about US $ 4000 per MT.

In 2004, estimated world production of honey was higher than the medium term average of 1.38 million MT. Beewax productions was also higher, 60,153 MT (FAO, 2005). In comparison to these amounts, production in sub Saharan Africa (Africa South of the Sahara 16 countries excluding the Republic of South Africa) was 135,375 MT of honey and 14,165 MT of beewax, most of which came from a very few countries. Much of African honey production is gathered rather than framed, sprivate sector modern production with many movable frame hives and inputs such as winter or out of season feeding and use of disease prevention measures is largely unknown in sub Saharan Africa.

Recognition of critical role of markets in economic development led to comprehensive market reforms across a number of developing countries. In spite of these reforms, symptoms of poorly functioning markets in much of Sub – Saharan Africa are evident in the segmentation of markets, low investment in the market infrastructure, the persistence of high margins and of the market thinness and the limited progression toward more complex arrangements (Eleni, 2001).

2.8 Wood raw materials

Wood is a natural anisotropic material with variations in material parameters in different directions and can be generally divided into hardwood and softwood. Every year trees have annual growth in both the longitudinal and the radial directions; the growth of new cells expands the diameter of the tree. Some wood species has relatively low density, less abrasive to processing equipment and derived from a renewable resource.

2.8.1 The Nature of wood

Wood is a natural polymer consisting primarily of cellulose, hemicellulose, and lignin in a matrix that provides structural support to the living tree and some resistance against microbial attack. Cellulose, because of its partial crystallinity, is somewhat resistant to microbial attack. Lignin is a heterogeneous polymer of phenyl propane units and is extremely resistant to some decay fungi (Scheffer and Morrell (1998**)**. Nevertheless, other organisms have developed the ability to attack one or more of the polymers in thewood cell wall. The nature of the differences in natural durability between wood from old and second-growth forests is unclear. In general, heartwood from virgin (old growth) stands of naturally durable species is more durable than that from second-growth stands (Anderson *et al.* 2015).

To appreciate natural durability of wood, it is important to understand how a tree develops. Each year, new woody layers are added over pre-existing ones. They are continuous from top to bottom and may be thought of as a stack of hollow cones. Each cone is slightly larger than the previous one, causing the tree to get bigger.

As the tree gets older and larger, storage cells in the center at the bottom begin to die. Various chemicals are formed from their contents, and additional materials move into the wood. As this part of the tree fills with natural chemicals, it becomes what is called

``heartwood''. With further aging, the heartwood core expands outward and upward. Increasing amounts of formerly conductive “sapwood” are therefore changed into heartwood (figure 1). Although all trees develop heartwood, not all heartwood chemicals are ``created equal''. Trees with more toxic natural chemicals have very durable heartwood. Other trees have only moderately resistant heartwood and some have no decay or insect resistance. In all trees though, even those with very durable heartwood, sapwood (Fig 1) has almost no resistance to insects and decay (Julian, 1998).

Plate 1: Location of heartwood and Sapwood (FPMDI,1998)

2.8.2 Tree Species under Study

Terminalia superba

Terminalia superba (Afara) is in the family *Combretaceae.* It has a broad distribution in West and Central Africa. It is widely used as a plantation species both within and outside its natural range. Supplies in the southern parts of its range have dwindled so that forest management and restocking are now needed in those areas where the best quality wood occurs (Groulez and Wood, 1985).It grows in deciduous moist forest and evergreen rain forest, where it colonises abandoned agricultural land. It prefers a climate with an annual rainfall of 1400-2000mm, a dry season and a mean annual temperature of 23-26°C. It favours fertile soils of alluvial origin but will grow on a variety of other soil types. The detailed ecological requirements of *T. superba* are discussed by Groulez and Wood (1985). *Terminalia superba* is a large-sized deciduous tree which normally grows to around 30 m but may grow to over 50 m. It is characterised by large buttresses, light-coloured smooth bark, leaves with long petioles and oblong, winged fruits. Depending on where it is grown, the wood is yellowish to brownish-black and of varying hardness and weight. Its wood is not durable, can be easily worked but has a tendency to split when nailed or screwed (Lamprecht, 1989).

Gmelina arborea

Gmelina arborea is a fast growing species member of Verbenaceae family and it is a major international timber species over a wide range of sites in the tropics. Its altitudinal range is approximately 50 to 1300 m in areas with distinct dry seasons in the countries of Bangladesh, Cambodia, China (Yunnan and Kwangsi Chuang provinces), India, Laos, Myanmar, Nepal, Pakistan, Thailand, and Vietnam (Dvorak, 2003). *Gmelina arborea* (Gmelina) is a medium to large tree that reaches 35 m in height in natural stands in tropical and subtropical regions of Asia (Dvorak, 2003). Hossain (1999) described *Gmelina arborea* as a medium-sized deciduous tree up to 40 m tall and 140 cm in diameter, but usually smaller than this. Duke (1983) described this specie as a deciduous tree 12-30m height and 60-100 cm in diameter. It was introduced to tropical Africa from South-East Asia (Ogbonnaya *et al*., 1992).

Gmelina arborea timber is reasonably strong for its weight. It is used for pulp, constructions, furniture, carriages, sports, musical instruments and artificial limbs. Once seasoned, it is a very steady timber and moderately resistant to decay and ranges

from very resistant to moderately resistant to termites. Its timber is highly esteemed for door and window panels, joinery and furniture especially for drawers, wardrobes, cupboards, kitchen, camp furniture and musical instruments because of its lightweight, stability and durability. In boat building it is used for decking and for oars (Dvorak, 2003). *Gmelina arborea* is a popular timber for picture and slate frames, turnery articles and various types of brush backs, brush handles and toys also for handles of chisels, files, saws, screw drivers, sickles, etc. The wood is also used for manufacturing tea chests and general purpose plywood, blackboards, frame core and cross bands of flush door shutters. In the instrument industry, Gmelina timber is widely employed for the manufacture of drawing boards, plane tables, instrument boxes, thermometer scales and cheaper grade metric scales. It is also used in artificial limbs, carriages and bobbins. It is an approved timber for handles of tennis rackets, frames and reinforcements of carom boards and packing cases and crates. Gmelina is used in papermaking and matchwood industry too (Kimmins, 2004).

Gmelina arborea leaves are considered good for cattle (crude protein – 11.9%) and are also used as food to silkworm (Dvorak, 2003) The root and bark of *Gmelina arborea* are claimed to be cure for stomach ache, improve appetite, useful in hallucination, piles, abdominal pains, burning sensations, fevers, and urinary discharge. Leaf paste is applied to relieve headache and juice is used as wash for ulcers. Flowers are sweet, cooling and bitter, they are useful in leprosy. The plant is recommended in combination with other drugs for the treatment of snakebite and scorpion sting (Kimmins, 2004).

Triplochiton scleroxylon

Triplochiton scleroxylon (Obeche) is widely distributed in the West and Central African forest zone from Guinea east to the Central African Republic, and south to Gabon and DR Congo. It is commonly planted in its natural area of distribution (e.g. in Côte d'Ivoire, Ghana and Nigeria). *Triplochiton scleroxylon* is characteristic of semi-deciduous forest, where it often grows gregariously, but it can sometimes be found in clearings in dense evergreen forest and in dry forest. In Nigeria it is almost exclusively limited to moist or rain forest areas at low and medium altitudes. It occurs up to 900 m altitude in regions with an annual rainfall of up to 3000 mm, but is most abundant at 200–400 m altitude and in areas with an annual rainfall of 1100–1800 mm and 2 rainy

seasons. It prefers more fertile, well-drained, ferruginous soils with light or medium texture and acid to neutral ph. It does not tolerate waterlogging, and in general avoids swamps.

The heartwood is whitish to pale yellow, indistinctly demarcated from the sapwood, which is up to 15 cm thick. The grain is usually interlocked, sometimes straight, texture moderately coarse. The wood has a ribbon-like aspect on quarter-sawn faces, and is lustrous. Fresh wood has an unpleasant smell, which disappears upon drying. The wood of *Triplochiton scleroxylon* is lightweight, the density is 320–440(–490) kg/m³ at 12% moisture content (Siepel *et al*, 2004).

The shrinkage rates are moderately low, from green to oven dry 2.5–4.1% radial and 4.2–6.6% tangential. The timber dries easily and rapidly, with only a slight risk of distortion and checking. The use of large spacer sticks is recommended during air drying to allow good air circulation. Once dry, the wood is stable in service. At 12% moisture content, the modulus of rupture is 52–110 N/mm², modulus of elasticity 4800–9200 N/mm², compression parallel to grain 24–43 N/mm², shear 3–8 N/mm², cleavage 5–15 N/mm.

Khaya grandifoliola

Khaya grandifoliola is a large dominant forest tree of up to 40 m high, bole to 23 m long by 9 m girth, buttressed to 3 m high, or more, leaning, sometimes twisted or lowly bifurcate of drier northern parts of the forest zone and forest outliers in the transition savanna it of the Meliaceae family (Burkill, 1985). They are grown from Guinea Bissau to an eastern limit in northern Uganda, this species is found largely on alluvial valley soils of gallery forest and beside streams in higher-rainfall savanna. Among many others uses this species is used as firewood, charcoal, timber (veneer, panelling, cabinet making and superior joinery), shade, ornamental (avenue tree), soil conservation and improvement, river-bank protection. The bark is pale grey, upper bole smooth but cracking into irregular scales near the base often serves as pain-killers, settles stomach troubles and subcutaneous parasitic infection. As a timber product, *Khaya grandifoliola* is used in carpentry and related applications and the exudate as gums, resins, etc. The leaves are even pinnate to 50cm long clustered at branch ends with 6-10 stiff shiny leaflets, each one more than 12cm long and 5cm across, the tip with a sharp point, often twisted. The flowers of *Khaya grandifoliola* are cream white in heads to 35cm beside leaves. The fruits are rounded woody capsule, grey-brown,

about 7cm diameter, breaking into 5 parts to release flat, oblong red-brown winged seeds. Seedlings (sow seed in pots), wildings. The capsules are very high up on the mother trees and the seeds are widely scattered when they split. *Khaya grandifoliola* suffers from shoot borers. Trees that have grown in savannah have darker timber than riverine ones. The timber has good working qualities, taking a high polish, and resembles true mahogany (Swietenia) more than other Khaya species. This species is particularly recommended for reforestation of river banks

Cordia millenii

Cordia millenii also known as Omo (Nigeria) and Ebe (Cameroon) is widely distributed in tropical Africa, found in closed forests and old secondary formations. The Tree grows to a height of 60 to 100ft, bole cylindrical, but rarely straight, 30 to 40 ft. in length; trunks about 3ft in diameter above buttresses (Chudnoff, 1984). Heartwood are pale golden brown to medium brown occasionally with a pinkish tint; sapwood lighter with coarse texture and grain typically interlocked. Basic specific gravity (oven dry weight/green volume) about 0.34; air-dry density 25pcf.*Cordia milleni* dries rapidly and well with only a slight tendency to warp. A high temperature kiln schedule is necessary to remove moisture pockets. Kiln schedule T1 3-C4S is suggested for 4/4 stock and T1 1 -D3S for 8/4. Shrinkage green to oven dry: radial 3.4%; tangential 4.6%; volumetric 7.5%. Movement in service is rated as small. It working Properties is described by Bolza, and Keating (1972) as well with hand and machine tools and is easy to finish, in planning there is some tearing of interlocked grain, nails satisfactorily. Generally, heartwood of *Cordia milleni* may be rated as moderately durable. And it is resistant to preservative treatments. *Cordia milleni* is used for Fine furniture and cabinetwork, joinery, and other decorative work where strength is not important (Chudnoff, 1984).

2.8.3 Chemical Composition of Wood

Wood is a lignocellulosic material; the main components of the lignocellulosic materials are cellulose, hemicellulose and lignin. Each of these components contributes to fiber properties, which ultimately impact product properties. Wood is essentially composed of cellulose, hemicelluloses, lignin and extractives. Cellulose is present in the form of thin microfibrils, about 5 nanometers in thickness and indefinite length. Cellulose is a glucan polymer consisting of linear chains of 1, 4- b-bonded

anhydroglucose units. The notation 1, 4-b describes the bond linkage and the configuration of the oxygen atom between adjacent glucose units (Klemn, 2005). The number of sugar units in one molecular chain is referred to as the degree of polymericzation (DP). Even the most uniform sample has molecular chains with slightly different DP values. Cellulose, the major chemical component of fiber wall and contributing 40-45% of the wood's dry weight is composed of linear chains of D-glucose linked by ß-1, 4-glycosidic bonds (Klemn, 2005). Cellulose is a major structural component of cell walls and it provides mechanical strength and chemical stability to plants. Solar energy is absorbed through the process of photosynthesis and stored in the form of cellulose.

2.8.4 Wood Moisture Content

Wood is a hygroscopic material which means that it absorbs and desorbs moisture from the surrounding air. Wood has very good water transportation properties because it needs water to grow. After the tree is cut down and sawn in to timber, many of these water transportation properties remain. The moisture content (MC) in wood is therefore dependent on the relative humidity (RH) of the surrounding air. Moisture in wood can either be found as moisture in the cell wall or as free water inside the lumens. Increased MC in the cell walls will decrease the mechanical properties of wood. This is due to water penetrating the cell wall which will weaken the hydrogen bonds that hold the cell wall together.

Dimensional changes of wood caused by moisture content changes are considerable. Wood's cell wall swells about 45% from the 0% moisture content to saturation fibre point. In tangential directions, the shrinkage from green to 6% moisture content varies from 4 to 9%, while in radial direction, for the same conditions, and varies from 1.8 to 6% (Zobel and Jett 1995). This can cause deformations and splits to wood boards, during their drying and their use. With the aim to improve its dimensional stability and to reduce its volumetric changes, the wood can be modified by means of different methods.

2.8.5 Physical Properties of Wood

There are several factors affecting the strength of timbers and the nature of the material is such that widely differing results can be obtained from differing specimens of the same species (Taylor *et al*, 2007).

Moisture Content

Dinwoodie and Desch (1996) defined moisture content of wood as the mass of water in the wood piece expressed as the percentage of the oven-dry mass of that piece. It has influence on all the properties of wood. Panshin and de Zeeuw (1980) asserted that below the fiber saturation point, most of the strength properties of wood vary inversely with its moisture content. Below the fiber saturation point, as the moisture content decreases the adsorption force that holds water to the wood becomes greater. Hence, as wood approaches the dry condition, low adsorption of polymonomolecular is involved.

Wood is a hygroscopic material that absorbs and losses moisture from and to the environment. The moisture content of wood is a function of atmospheric conditions and depends on the relative humidity and temperature of the surrounding air (Arntzen and Charles, 1994). Wood reaches equilibrium moisture content (EMC) when temperature and humidity is constant. Under this condition, the wood neither gains or losses moisture to the environment. At EMC wood is in symmetry with its environment (Arntzen and Charles, 1994).

In structural applications, moisture content of wood undergoes gradual and short-term changes with varying temperature and humidity conditions of the prevailing environment. These changes affect only the surface of the wood. Wood in service requires time to reach its EMC and this is dependant basically on the (a) size and permeability, (b) temperature and the moisture difference and (c) EMC potential of the members. According to Arntzen and Charles (1994), fluctuations in woods moisture content cannot be stopped entirely but can be minimized by the application treatments or coatings on the surface of the wood.

Bound Water

Bound water (monomolecularly adsorbed water, hygroscopic water, or imbibed water) is contained in the cell walls (the secondary pore space) i.e. transient cell wall

capillaries and the amorphous regions of the cellulose micro fibrils. The hydroxyl groups of cellulose molecules in the amorphous regions attract molecules of water and are linked to them by hydrogen bonding (Ofori, 2004b).

Fibre Saturation Point

In drying of wood, the 'free' water evaporates first, followed by the bound water. The condition existing when all the free water has been evaporated and the cell walls are still completely saturated is termed the Fibre Saturated Point (FSP). It usually occurs at moisture contents between 24 – 30%. It varies with different wood species and somewhat within individual pieces of wood. The variation is caused by differences in the chemical composition, crystallinity of the cellulose, compactness of the cell wall, specific gravity and extractive content. The moisture content corresponding to the FSP varies with temperature also, decreasing as temperature increases. It is also affected by prolonged exposure of wood to high temperatures which results in a permanently reduced FSP. The condition of wood at FSP is associated with maximum swollen volume of the cell wall and with major changes in the physical behaviour of wood, and hence is of primary importance. Shrinkage is normally defined as the reduction in size which occurs wood dries from the condition down below the fiber saturation point. Below the FSP most properties are negatively correlated with moisture content. Below the FSP wood exhibits improved electrical resistance, resistance to decay, and better gluing characteristics and nail-holding power, and a continued reduction in density. Values of FSP are determined by procedures that include;

i. Extrapolation to 100% relative humidity of sorption data on equilibrium moisture content,
ii. Observation of shrinkage initiation with loss of moisture,
iii. Analysis by the polymer exclusion technique (Stamm, 1971).

Density of Wood

The density is the mass per unit volume of a given substance. It is expressed either in; (a) kilograms per cubic meter (kg/m3), (b) pounds per cubic foot (lb/ft3), or (c) grams per cubic centimeter (g/cm3) (Forest Product Laboratory, 2010). Density of hygroscopic material such as wood depends on two factors; (1) weight and (2) moisture held in the wood structure. The density of a wood is a good index of its

properties with the proviso that clear, straight grained, and free from defects are prerequisite to its application.

According to Forest Product Laboratory (FPL) report 2010, the density of oven dry wood varies significantly between species. The report further stated that within a given species, variation in oven dry density can be attributed to the anatomical characteristics of wood such as early wood to latewood and heartwood to sapwood ratios.

Wood density has influence on the strength of timber, pulp yields, fuel values and numerous other important properties (Reid, 2009). Even though the wood of some species is naturally heavier than others, it is important to appreciate density variations within the tree. According to Kollman and Cote (1984), wood density is strongly related with strength properties, for example compressive strength and bending strength. Chowdhury *et al*. (2009) in related study asserted that, compressive strength is related to density and it increases from the pith to the bark. Wood density is a complex trait, especially in angiosperms, where fibers and vessels are surrounded by other cells and vessels are surrounded by other cells, for example rays and parenchyma (Zhang and Zhong, 1992).

Shrinkage and Swelling

Wood changes dimension, (shrinkage and swelling,) take place below the FSP where all of water exists only within the cell wall. Shrinkage and swelling is proportional to the amount of water exchanged between a piece of wood and its environment. Wood is an anisotropic material – its dimensions change differently the in three principal directions: tangentially, radially, and longitudinally. The highest rate of change is observed in the tangential direction basically due to parallel orientation of microfibrils along the axis of the cell wall. Following tangential shrinkage is the radial whereas longitudinal shrinkage is negligible for normal mature wood and for most practical applications. Tangential shrinkage in wood therefore is approximately twice radial shrinkage.

Wood is also a hygroscopic material and therefore loses and gains moisture as a result of changes in humidity of the prevailing environment (FPL, 2010). The hygroscopicity nature makes wood distinct from other materials. Every wood product will absorb moisture from the surrounding air until it reaches equilibrium moisture content.

Hygroscopic materials such as wood and other lignocellulosic material change their dimensions with fluctuations in relative humidity of the surrounding environment. For this reason, it is important to determine moisture content of wood products before they are used.

Heartwood and Sapwood

The dark-coloured center portion of wood is the heartwood whereas the lighter tissue is known as the sapwood. Heartwood always contains amount of extractives higher than the sapwood and extractives do inhibit normal shrinkage by bulking the amorphous regions in the cell wall structure (Chong and Fogg, 1989).This explains why heartwood shrink less than the sapwood and which affects the physical properties of wood.

2.8.6 Chemical Properties of Wood

Wood is primarily composed of lignin, cellulose, hemicelluloses, and extractives. Each of these components accounts for the wood's properties, which ultimately impact properties of the product made from the wood (Sjostrom, 1993). Wood is a three dimensional biopolymer composite composed principally of carbon, hydrogen and oxygen. Wood also contains inorganic compounds that remain after combustion in the presence of oxygen. Wood is connected with chains of cellulose, hemicellulose and lignin with little amounts of inorganic compounds and extractives (Brown, 1997). In addition to these major constituents, the cell wall also contains pectins and extractives.

Holocellulose in Wood

Holocellulose is the combination of 40 – 45% of cellulose and 15 – 25% of hemicelluloses which accounts 65 – 70% of the weight of dry woods. The cellulose and hemicelluloses form the major carbohydrate content of the wood. There are also little amounts of other sugar polymers such as starch and pectin (Stamm, 1964).

Cellulose

Cellulose is produced from a glucose-based sugar nucleotide. A nucleotide is a compound derived from combining a sugar with a phosphate group and a base that is a component of RNA or DNA (Kozlowski and Pallardy, 1997). Cellulose is a linear polymer of (β-1→4) D – glucopyranose. It occurs primarily in the S2 layer of the cell

wall of wood and is present in only smaller quantities in the compound middle lamella. It increases as a proportion of dry weight of the cell wall through the center of the S2 layer. Wood cellulose is about 60 to 70% crystalline and 30% amorphous (Kollman and Cote, 1968). Cellulose chains are grouped together into microfibrils arranged in a helical structure in each layer of the wood cell wall. Cellulose is the strongest polymer in wood accounting for strength in the wood fiber because of its linear orientation and high degree of polymerization. Cellulose dissolves in strong acids and insoluble in alkali. The structure of cellulose can resist failure in tension (Sjostrom, 1993).

Lignin

Lignin is a three dimensional polymer composed of phenyl propane units. It has irregular structure and cannot be isolated from wood without degrading the wood (Kollman and Cote, 1968). Lignin is found between individual cells and within the cell walls. It serves as a binding agent between the individual cells whilst within the cell walls, lignin is very closely related with cellulose and the hemicelluloses to give rigidity to the cell (Peng *et al*., 2002). The compound middle lamella has higher lignin content and is highly concentrated throughout the secondary wall.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

This research work was carried out in four locations within Oyo and Ogun States, South-West Nigeria (Figure 3.1). The two states cover a total land area of 27,249 and 16762km^2 respectively. The topography of these states is one of gentle rolling lowland in the Southern Nigeria, rising to a plateau 40 and above in the North. The two states are well drained with rivers flowing from the upland in the North/South direction. They have two distinctive climate seasons, the rainy season and the dry season with maximum temperature of 34.5^{o}C, 40.0^{o}C and minimum temperature of 25.7^{o}C, 20.0^{o}C respectively.

3.2. Data Collection

Data collection was carried out in three phases. Phase one involved questionnaire administration to selected beekeepers in the study area to elicit information on the species of wood commonly used for hives construction in the study area. Phase two involved procurement of the five prioritized wood species, construction of the hives, baiting of the hives, rearing of the bees and harvesting of the honey. Phase three involved assessment of physical properties and phytochemical composition of wood,and proximate analyses of the harvested honey.

3.2.1 Sampling Procedure

Two locations (Oyo and Ogun States) were purposively selected. In each state, two beefarming communities were visited for the purpose of data collection. In Oyo State, Onifuufu and Ogunmakin communities were visited, Adeaga and Ayetoro communities were visited in Ogun State.

3.2.2 Sampling Population

In each of the States, two communities were visited, 20 beekeepers in Onifuufu, 12 beekeepers in Ogunmakin, 32 beekeepers in Adeaga and 16 beekeepers in Ayetoro were interviewed giving a total number of Eighty (80) respondents that were used for the purpose of questionnaire distribution.

3.2.3 Procurement of raw materials and Hive Construction

Box (Top Bar Hive) is the oldest and most commonly used hive style in the world. It features individual bars (Top Bars) laid across the top of the hive cavity. The bees build their comb down from these bars naturally without the use of a four sided frame or wall. Generally, the bars are a wooden wedge with a guild to ensure combs hang straight. A light metal roof which allows optimum runoff of rainfall, easy opening and closure which improves the durability of the hives.

The wood of five species *Cordia milleni*, *Terminalia superba*, *Gmelina Arborea*, *Triplochiton scleroxylon* and *Khaya grandifoliola* were procured from sawmill in Ibadan. The woods were used to construct Kenya Top bar beehives in the workshops of carpenters who are beehives specialists. The hives were long trough formed box with slanting sidewalls with 22 top bars of 28 cm long. It comprises of a base load up, two side walls and a front and back wall and four cuts of 0.8x8 cm each in front wall as flight entrance for the bees.

3.2.4 Placement of hives

Five Kenya top bar hives (Plate 3.1) with 3 replicates were placed in September to December in each of the 4 communities, making a total number of 60 hives. The hives were placed on iron stand of 1m in height. The 22 top bars, inner part of the hives, side walls and the flight passage were coated with residues of beeswax and left for colonisation by bees and observed on a monthly basis for a year. Time taken by each hive to colonise was recorded and the time the bees absconded from the hives were also observed and recorded. Hive inspection for pests was done fortnightly to assess cases of pest attack on hives.

3.2.5 Evaluation of Absconding Tendency

Absconding tendency was observed by the ratio of colonies evacuating to the total number of colonies used for the experiment.

3.2.6 Evaluation of Honey yield

Honey yield was determined after extraction. After extraction, the container where the honey was poured was weighed before pouring the honey, i.e. empty container, then weight of the container with honey:

Weight of container =?

Weight of container with honey =?

Weight of honey = (Weight of container with honey) – (Weight of container)

3.2.7 Preparation of Test Specimens

The specimens for determining the physical properties were prepared from radial planks cut from the wood logs. The planks were sawn and subsequently planed. Specimens of 60 mm in the longitudinal and 20 mm each in the radial and tangential directions were obtained from the pith to the outer part of the trunk. Sampling methods and number of samples were according to International Organization for Standardization ISO 3129 (1975). The laboratory determination was carried out on test specimens in their green state.

3.2.8 Physical Properties of the Wood Samples

These tests were performed in accordance with ISO 3130 (1975) for moisture content determination, ISO 3131 (1975) for density determination, ISO 4469 (1981) for tangential and radial shrinkage determination and ISO 4858 (1982) for volumetric shrinkage.

Wood specimens were weighed and their dimensions were measured. The specimens were dried in a constant climate chamber (20 ^{o}C temperature and 65 % relative humidity) until 12% moisture content, a point at which the specimens attained constant weight (<0.1 % weight change within 24h). Subsequently, the specimens were re-weighed and re-measured. They were dried in an oven at 100±3 ^{o}C until a constant dry

weight was reached. The results were used to determine the moisture content, density and shrinkage in the radial, tangential and longitudinal sections.

To determine the volumetric shrinkage, air-dry samples were kept in distilled water for one week, and their tangential, radial and longitudinal dimensions were measured. The samples were then dried in an oven at 100±3 °C. Following drying, the sample dimensions were re-measured.

Calculations

Density:

$$\text{Density} = \frac{\text{Oven-dry weight}}{\text{Oven-dry volume}} \quad \text{Kg/m3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eqn 3.1)}$$

Moisture content:

$$\text{M.C} = \left(\frac{w1-w2}{w2}\right)100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(eqn 3.2)}$$

Where:

M.C= Moisture content

W_1= Initial weight (green weight)

W_2= Final weight (oven dried weight)

Shrinkage in the tangential, radial or longitudinal direction:

$$\beta\% = \left(\frac{initial\ dimension - fin\quad dimension}{initial\ dimension}\right) X100 \quad \text{.....(eqn 3.3)}$$

Initial dimension = saturated dimension

Final dimension = oven-dry dimension

Volumetric Shrinkage:

$$\boldsymbol{\beta_v = \beta_t + \beta_r + \beta_l} \quad \text{.....(eqn 3.4)}$$

β_r = Radial shrinkage

$\boldsymbol{\beta_l}$ = Longitudinal shrinkage

β_t = Tangential shrinkage

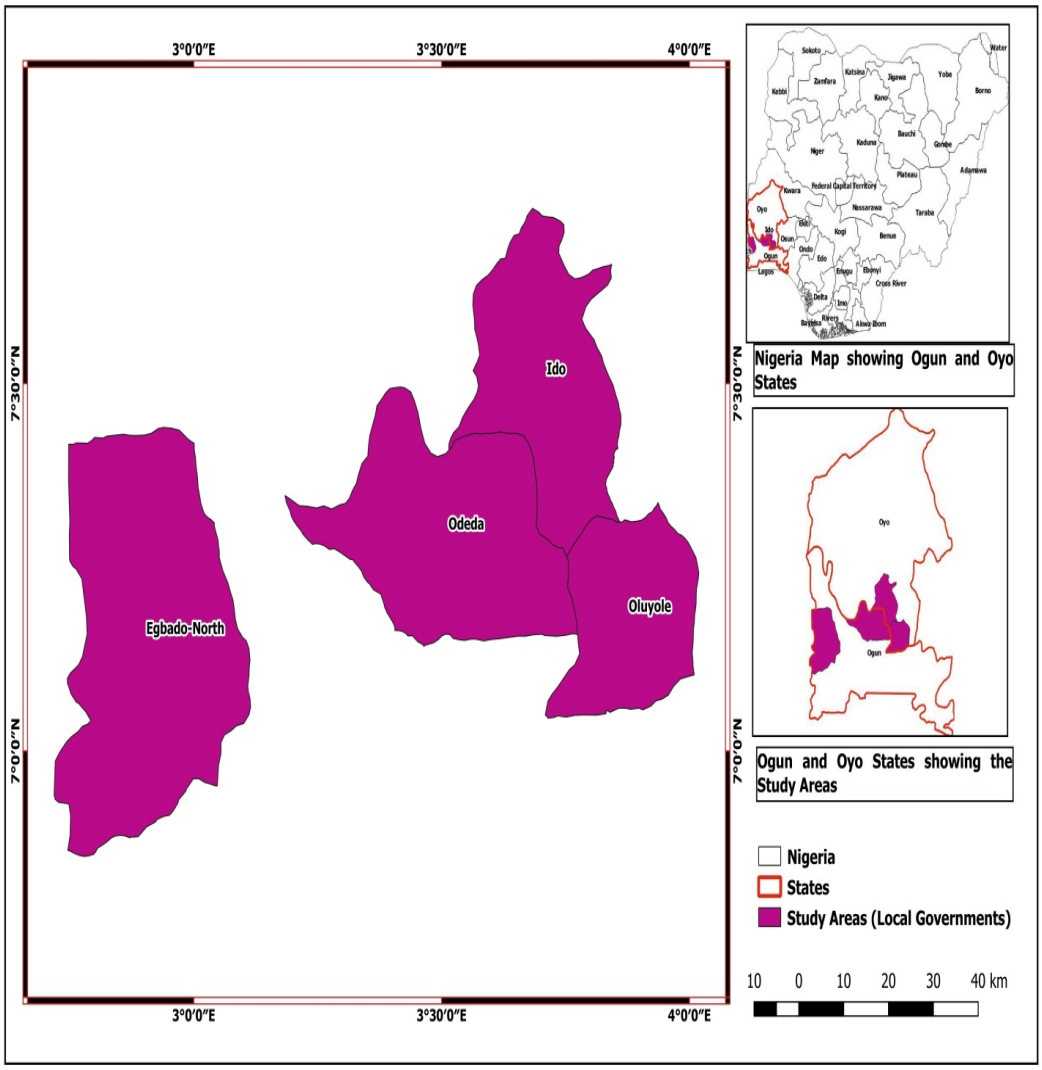

Figure 3.1: Map of Nigeria showing the study Area

Plate 3.1: Kenya Top bar hive with 22 top bars

Plate 3.2: Top bars housing the honey combs in a beehive

Plate 3.3: Author with a top bar with honey comb

Plate 3.4: Colonised beehive

3.2.9 Chemical composition of the wood samples

3.2.9.1 Determination of Cellulose

One gram of each wood sample was weighed and transferred into a 250cm^3 Erylenmeyer flask. Then, 50cm^{3}of 96% ethyl alcohol and 25cm^3 of 65% nitric acid was added. The flask was put on a heater equipped with condenser and heater for 60 minutes. After hydrolysis, the flask contents were filtered. Once more, remaining cellulose on the filter paper was transferred into the flask, and the process was repeated twice, the cellulose together with the filter paper was dried at 120^o C. The cellulose content was calculated using the following equation.

$$\text{Cellulose\%} = \frac{\text{Cellulose dry weight}}{\text{Sample dry weight}} \times 100 \quad \text{.....(eqn 3.5)}$$

3.2.9.2 Determination of Hemicellulose

Hemicelluloses are non-cellulose, non-pectic cell wall polysaccharides. They are categorized under “unavailable carbohydrate” since they are not splited by the digestive enzymes of the human system. A neutral detergent solution was prepared by weighing 18.6g of disodium ethylene diaminetetraacetate and 6.8g of sodium borate decahydrate into a 1000cm^3 beaker and dissolved in a 200cm^3 distilled water by heating. To this a 150 cm^{3}solution containing 30g of sodium Lauryl sulphate, 10cm^3 of 2-ethoxy ethanol and 100cm3 solution containing 4.5g of disodium hydrogen phosphate were added. The volume made up to 1000cm^3 and the pH of the solution was at pH 7.

To 1.0g of each wood powder in a refluxing flask, 10cm^3 of cold neutral detergent solution was added followed by 0.5g Sodium sulphate. The mixture were heated to boiling and refluxed for 60 minutes. The solution was filtered through a Whatman filter paper No 42 (125mm) and the residue in the paper washed twice with acetone. The filter paper with the residue was dried in an oven at a temperature of 100^{0}C for 8 hours. The filter paper and its content were cooled in a desiccator and weighed (Goering and Vansoest, 1975). Hemicellulose was calculated as:

Hemicellulose= Neutral detergent – Acid detergent …… (eqn 3.6)

Fibre (NDF) Fibre (ADF)

3.2.9.3 Determination of Total Lignin Content

The total lignin content of the wood was determined by the determination of the soluble and insoluble lignin. The summation of the soluble and insoluble lignin gave the total lignin. In the insoluble lignin determination, 2.0g of each wood powder was impregnated with 3cm^3 of 72% tetraoxosulphate VI acid and placed in a water bath at a controlled temperature of 30^{o}C for 60 minutes, after which 68cm^3 of deionized water was added to the mixture. The conical flask and its content (mixture) were heated in an autoclave at 125^{0}C for 75 minutes. The conical flask with its content was left to cool and the lignin filtered. Deionized water was used to wash the insoluble lignin until a neutral pH was achieved. It was then oven dried at a temperature of 80^{o}C to a constant weight (Hikino *et al.,* 1984). The lignin content was calculated by the following formula:

$$IL = \frac{W\ lignin}{W\ fibre}\ x\ 100 \quad \text{……..(eqn 3.7)}$$

Where IL = Insoluble lignin content (%)

W lignin = oven-dry weight of insoluble lignin (g)

W fibre = oven-dry weight of wood fibres (g)

The filtrate obtained from the insoluble lignin was used to determine the soluble lignin content in tetraoxosulphate VI acid by spectrophotometric method. In this method, 5cm^3 of 3% tetraoxosulphate VI acid was added to 5cm^{3}of the insoluble lignin filtrate. An ultraviolent (UV) spectrophotometer was used to measure the absorbance of the solution at a wavelength of 205nm (Goering and Vansoest, 1975). The soluble lignin content was calculated using the equation below:

$$SL = \frac{CV\ X\ 100}{1000\ X\ Wfibre}\ x\ 100 \quad \text{……..(eqn 3.8)}$$

Where SL = soluble lignin content (%)

C = concentration of soluble lignin in the filtrate (g/L).

V = total Volume of the filtrate (cm^3)

W. fibre = oven-dry weight of wood fibres (g)

3.2.9.4 Preparation of test specimens for phytochemical contents determination

The wood samples (cut to small pieces) were air dried for 6-7 days. The dried samples were powdered using a mechanical blender to obtain fine size. Five grams of the sample was extracted using aqueous: methanol (1:1), and then 150 mL each of ethanol and ethyl acetate on a soxhlet apparatus. Exhaustive extraction was performed by 20 cycles in the extractor. The extracts were concentrated using flash evaporator and the concentrated extracts were collected in cleaned glass vials (Muthukumaran *et al*., 2016).

3.2.9.5 Determination of total phenolic contents

Total phenolic content was determined on the aqueous methanol, ethanol and ethyl acetate extracts of the five wood species by making 20 µL of the extract up to 1 mL with distilled water. Then, 0.5 mL of freshly prepared Folin ciocalteu phenol reagent and 2.5 mL of 20 % sodium carbonate were added in turn. The contents were shaken and left to stand in the dark for 40 minutes. The absorbance of the sample was read at 725 nm. Gallic acid standard was used to construct a calibration curve (Muthukumaran *et al*., 2016). The phenolic content was expressed as mg gallic acid/100 g of wood.

3.2.9.6 Determination of total flavonoid content

The aqueous-methanol extract (0.1 mL) was made up to 5 mL with distilled water and 0.3 mL of 5% sodium nitrite was added. After 5-minute period, 3 mL of 10% aluminum chloride was added and the mixture was well shaken. After 6-minute period, 2 mL of 1M NaOH was added and shaken, and the absorbance was read at 510 nm (Sathishkumar *et al*., 2013). Quercetin was used as standard to construct a calibration curve. The flavonoid contentwas expressed as mg quercetin/100 g of wood.

3.2.9.7 Determination of tannin content

The aqueous extract (100 µL) was made up to 7 mL with distilled water; 8.0 mM of potassium ferric cyanide and 20 mM of ferric chloride in 0.1M hydrochloric acid were added in turn. The contents were mixed and optical density was measured at 700 nm

(Muthukumaran *et al*., 2016). Tannic acid was used as standard to construct a calibration curve. The tannin content was expressed as mg tannin/100 g of wood.

3.2.9.8 Determination of saponins

The aqueous-ethanol extract (100 mL) was heated on a hot water bath for 4 hours with continuous stirring at 55°C. The residue of the mixture was re-extracted with another 100 mL of 20% aqueous ethanol and filtered. This extract was heated for 4 hours at a constant temperature of 55°C with constant stirring (Ezeonu and Ejikeme). The combined extract was evaporated to 40 mL on a water bath at 90°C. 20 mL of diethyl ether was added to the concentrate in a 250 mL separating funnel and vigorously shaken. The funnel content was allowed time to stand and the layers separated. The aqueous layer was collected while the ether layer was discarded. This purification process was repeated two more times. 60 mL of butanol was added and extracted twice with 10 mL of 5% sodium chloride. the sodium chloride layer was discarded and the remaining saponin solution was heated on a water bath for 30 minutes. the solution was transferred into a porcelain crucible and dried in an oven to a constant weight. The saponin content was calculated as a percentage:

$$\% \text{ Saponin} = \frac{Weight\ of\ saponin}{Weight\ of\ sample}\ x\ 100 \quad \text{..... (eqn 3.9)}$$

3.2.9.9 Determination of total alkaloids

Five grams of powdered wood sample was weighed and dispensed into 50 ml of 10% acetic acid solution prepared in ethanol. The mixture was well shaken and allowed to stand for 4 h before it was filtered. The filtrate was then evaporated to one quarter of its original volume on a hot plate. Concentrated ammonium hydroxide was added drop wise so as to precipitate the alkaloids. A pre-weighed filter paper was used to filter off the precipitate and it was washed with 1% ammonium hydroxide solution. The filter paper containing the precipitate was dried on an oven at 60^{o}C for 30 min, transferred into a desiccator to cool and reweighed until a constant weight was obtained (Shamsa *et al*., 2008). The weight of the alkaloid was determined by weight difference of the filter paper and expressed as a percentage of the sample weight analyzed.

3.3.0 Proximate Analysis of Honey

The following proximate analyses were carried out on the honey produced from the hives:

3.3.1 Test for Carbohydrates

Distilled water of 5cm^3 was added to 0.1g of honey sample and was left for 2 hours, shaken vigorously and filtered through Gem filter paper 173 (12.5cm). To the aqueous filtrate, three drops of Molisch's reagent (5% - 1-naphthol in alcohol) was added, followed by vigorous shaking. Then 1.0cm^3 of concentrated tetraoxosulpahte (VI) acid was carefully added to the inclined test tube and observed for a red-cum-violet ring (brown ring) at the junction of the two liquids, indicating the presence of carbohydrate (Hikino *et al*., 1984).

3.3.2 Total ash content

Silica dish was placed in muffle furnace for about 15 minutes at 350°C, after which it was removed and cooled in a desiccator for about 60 minutes and weighed and recorded. An amount of 2g of honey was added and put inside the crucible and then placed inside muffle furnace and slowly the temperature was increased to 450°C and this was done to avoid incomplete ashing, the crucible was removed to the desiccator and allowed to cool at room temperature, the crucible and honey were then be re-weighed.

3.3.3 Protein determination

To determine the protein, 2g of honey was weighed into 500ml kjeldahl flask, 20ml of concentrated H_2SO_4 was added; 0.5g of honey was weighed into 50ml micro kjeldahl flask and 5ml of concentrated H_2SO_4 was added. The samples were heated with low heat for about 25 minutes, later to be increased to medium heat for about 30 minutes again and finally at high heating until they were digested. The flask was rotated at intervals until the digest was clear (grey white) and heating continued for a few minutes to ascertain complete digestion. The samples were allowed to cool, observed, filtered and made to digest up to 50ml.

3.3.4 Viscosity

This was done with the aid of automatic viscous testing machine, the honey sample was poured into the cup of the machine as the spindle rotates and the readings were obtained at the calibrated surface.

3.4.0 Data analysis

3.4.1 The primary data obtained from the study was collated and analysed with statistical package for social sciences (SPSS). Descriptive statistics like frequencies and percentages were used to describe the variables and their occurrence among the respondents. Mean values were used as a measure of central tendency for variable measure at interval and ratio levels. Variables that indicate multiple responses were ranked in decreasing order of frequency. Analysis of variance (ANOVA) was used to analyse the data from the physical properties determined.

3.5 Experimental Design

The experimental design used was 4x5 factorial experiments in Completely Randomized Design (CRD), the combination of which was 20 factorial combinations with 3 replicate per treatment. The experiment was designed to include the following variables.

Honey yield (HY): Oyo and Ogun, Wood Species (WS): Wood species *(1, 2, 3, 4 ,5)* as outlined in Table 3.1.

Statistical Model for this Experiment was;

$$Y_{ijk} = \mu + S_i + W_j + SW_{ij} + \varepsilon_{ijk}$$

Where;

Y_{ijk} = Individual Observation

μ = General Mean

H_i = Effect of Honey yield

W_j = Effect of Wood Species

HW_{ij} = Interaction of Honey yield and Wood species

ε_{ijk} = Experimental Error

Table 3.1: Treatment Combinations

Honey yield in sites	Wood Species				
	KHG	GMA	COM	TRS	TES
Onifuufu Honey yield	KHGOnf	GMAOnf	COMOnf	TRSOnf	TESOnf
Ogunmakin Honey yield	KHGOgm	GMAOgm	COMOgm	TRSOgm	TESOgm
Adeaga Honey yield	KHGAdg	GMAAdg	COMAdg	TRSAdg	TESAdg
Ayetoro Honey yield	KHGAyt	GMAAyt	COMAyt	TRSAyt	TESAyt

CHAPTER FOUR

RESULTS

4.1 Socio-Economic Characteristics of the Respondents

In this section, the major socio-economic characteristics of households interviewed in the survey are described. These characteristics relate to the relative frequency distribution of household heads by gender, age, education level and marital status.

Table 4.1 presents frequency distribution of socio-economic characteristics of respondents. It is presented that more of the respondents 51 (63.8%) were between 40 and 49 years old, 20 (25%) were between 30 and 39 years old, 8 (10%) revealed to be 50 years old and above, while 1 (1.3%) claimed to be less than 30 years old. Sex distribution, 74 (92.5%) reported to be males, while 6 (7.5%) were females. Educational background, 47 (58.8%) revealed to have secondary school leaving certificate, 21 (26.3%) reported having post-secondary school certificate, 7 (8.8%) signified not having a formal education, while 5 (6.3%s) had primary school leaving certificate. Household size, most of the respondents 55 (68.8%) revealed to have between 8 and 14 household sizes, 18 (22.5%) had 15 and above, while 7 (8.8%) had less than 8 as their household size. Religion distribution revealed that most of the respondents 34 (42.5%) were Muslims, 27 (33.8%) were Christians, 14 (17.5%) were traditionalists, while 5 (6.3%) were for other religion. Years of experience in honey bee, most of the respondents 29 (36.2%) revealed to have between 16 and 20 years of experience in bee keeping, 21 (26.3%) has between 11 and 15 years of experience, 12 (15%) claimed having between 6 and 10 years of experience in bee keeping, 10 (12.5%) stated having 20 years and above experience in bee keeping.Ethnicity distribution revealed that most of the respondents 74 (92.5%) were Yorubas, 2 (2.5%) were Hausas, 2 (2.5%) were Igbos, while 2 (2.5%) belong to other ethnic group.

Table 4.1: Socio-Economic Characteristics of the Respondents

Variable	Response	Frequency	Percentage
Age	Less than 30 years	1	1.3
	30-39 years	20	25
	40-49 years	51	63.8
	50 years and above	8	10
Sex	Male	74	92.5
	Female	6	7.5
Educational background	Primary	5	6.3
	Secondary	47	58.8
	Post secondary	21	26.3
	No formal education	7	8.8
Household size	Less than 8	7	8.8
	8-14	55	68.8
	15 and above	18	22.5
Religion	Christianity	27	33.8
	Islam	34	42.5
	Traditional	14	17.5
	Other religion	5	6.3
Years of experience	6-10	12	15.0
	11-15	21	26.3
	16-20	29	36.2
	20 and above	10	12.5
Ethnicity	Yoruba	74	92.5
	Hausa	2	2.5
	Igbo	2	2.5
	Others	2	2.5
Total		**80**	**100**

Source; Field survey, 2017

4.2 Honey production

The amount of honey produced from one bee hive per year varies from places to places which in most cases determined by the availability of pollen and nectar source plants and the level of management and input applied.

Table 4.2a, revealed that most of the respondents 62 (77.5%) use white wood for beekeeping activities, while 18 (22.5%) signified using yellow wood. Most of the respondents 40(50%) revealed using *Gmelina arborea* for hive construction,17(21.2%) claimed using *Triplochiton scleroxylon,* 15 (18.8%) revealed using *Cordia Milleni,* 5 (6.3%) signified using *Terminalia superba*and 3(3.7%) claimed using *Khaya grandifoliola*. Beehives, most of the respondents 39 (48.3%) revealed having between 6 to 10 beehives, 21 (26.2%) had between 11 to 15 number of beehives, 10 (12.5%) had between 16 to 20 number of beehives, 5 (6.2%) had between 1 to 5 beehives, while 5 (6.2%) had 20 and above beehives. In addition, majority of the respondents 70 (87.5%) revealed that the sales of the honey produced is for financial purpose, while 10 (12.5%) stated that it is used for home consumption. Furthermore, majority of the respondents 78 (97.5%) claimed that there are problems encountered in the use of beehives, while 2 (2.5%) reported that no problem was encountered in the use of beehive. Among those who signified having problem with beehive (n = 78), 53 (67.9%) claimed that the problem they face is colonisation by bees, 15 (19.3%) revealed abscondment, while 10 (12.8%) signified theft challenges as a factor influencing their beehive farm.

Table 4.2b, 78 respondents revealed having problems with their beehives. 42 (67.9%) revealed that the problem they are facing was caused by the types of wood they use, 20 (25.6%) signified theft problem, 11 (14.1%) stated abscondment, while 5 (6.4%) claimed pest and diseases. Respondents were also asked whether bee colonise hive fast, most of the respondents, 51 (63.8%) agreed that bee colonise the hive fast, while 29 (36.2%) signified that bees do not colonise the hive fast. As a means of gathering knowledge, respondents were asked on factors they feel are responsible for quick colonisation, most of the respondents 30 (37.5%) revealed that availability of forage causes quick colonisation, 25 (31.3%) revealed that wood species selection affect quick colonisation, 15 (18.8%) revealed hive height placement, while 10 (12.5%) signified availability of shade.

Table 4.3 presents the five (5) identified wood species utilized mostly by the beekeepers in the study area. Initially, the researcher was able to identify fifteen (15) species of beehives used in the selected sites. The following species were identified in the study area; (50%) *Gmelina arborea*, (21.2%)Arere (*Triplochiton scleroxylon*), (18.8%) Omo (*Cordia millenii*), (6.3%)Afara (*Terminalia superba*), (12.5%) Ayunre (*Albizia zygia*), Ita (*Celtis zenken*), (3.7%) Mahogany (*Khaya grandifoliola*), (12.5%) Opepe (*Nauclea diderichii*), (8.75%) Ose (*Adansonia digitata*), (10%) Araba (*Ceiba petandra*), (11.25%) *Eucalyptus glubulus*, (8.75%) *Senna siamea*, (10%)Emi (*Butyrospermum parasoxum*), (7.5%) Iya (*Daniellia oliveri*), (Oori (*Vitellaria paradoxa*). However, only five (5) from the above mentioned species of wood are presently used by beekeepers in the selected areas. Most of the respondents, 40 (50%) used *Gmelina arborea* for beehives construction, 17 (21.2%) used *Triplochiton sceloroxylon*, 15(18.8%) revealed using *Cordia millenii*, 5 (6.3%) used*Terminalia superba,*while 3 (3.7%) used *Khaya grandifoliola.*

Ayunre (*Albizia zygia*), Eucalyptus glubulus, Ita (*Celtis zenken*), Opepe (*Nauclea diderichii*), Ose (*Adansonia digitata*), Araba (*Ceiba petandra*), *Cassia siamea*, Emi (*Butyrospermum parasoxum*), Iya (*Daniellia oliveri*), Oori (*Vitex doniana, Vitex grandfolia*) were the commonly used wood species that have been abandoned by the bee farmers due to their fragility and inability to sustain bee colonies.

Table 4.2a: Bee Colonisation, Abscondment and Yield

Wood type used	Frequency	Percentage
White wood	62	77.5
Yellow wood	18	22.5
Total	**80**	**100.0**
Specie used for hives construction (current hives)		
Triplochiton scleroxylon	17	21.2
Terminalia superba	5	6.3
Gmelina arborea	40	50
Cordia milenni	15	18.8
Khaya grandifoliola	3	3.7
Number of hives		
1-5	5	6.2
6-10	39	48.3
11-15	21	26.2
16-20	10	12.5
20 and above	5	6.2
Total	**80**	**100**
Uses of produce		
Sales for money	70	87.5
Home consumption	10	12.5
Total	**80**	**100**
Problems with bee hives		
Yes	78	97.5
No	2	2.5
Total	**80**	**100**
What problem is it?		
Colonisation	53	67.9
Abscondment	15	19.3
Theft	10	12.8
Total	**78**	**100.0**

Source; Field survey, 2017

Table 4.2b: Bee Colonisation, Abscondment and Yield

Wood type used	Frequency	Percentage
Causes of problems		
Type of wood	42	67.9
Abscondment	11	14.1
Pest and diseases	5	6.4
Theft	20	25.6
Total	**78**	**100.0**
Factors responsible for quick colonisation		
Forage Availability	30	37.5
Wood species selection	25	31.25
Hive height placement	10	12.5
Availability of shade	15	18.75
Total	**80**	**100.0**
Abscondment of honey colonies		
Yes	51	63.8
No	29	36.2
Total	**80**	**100.0**
Reasons for bee absconding hives		
Disturbance	32	40.0
Environmental factors	14	17.5
Climatic factors	14	17.5
Pest and diseases	12	15.0
Scarcity of forage	8	10.0
Total	**80**	**100.0**
Prevention of abscondment		
Regular feeding	8	10.0
Regular inspection	57	71.2
Colony migration	15	18.8
Total	**80**	**100.0**

Source; Field survey, 2017

Table 4.3: Compendium of wood species for beekeeping

Wood type used	Frequency	Percentage
Species used for hives construction (current hives)		
Triplochiton scleroxylon	17	21.2
Terminalia superba	5	6.3
Gmelina	40	50
Cordia milenni	15	18.8
Khaya grandifoliola	3	3.7
Other least use wood species (Abandoned or used before)		
Albizia zygia	10	12.5
Celtis zenken	8	10
Nauclea diderrichii	10	12.5
Adansonia digitata	7	8.75
Ceiba pentandra	8	10
Eucalyptus globulus	9	11.25
Senna siamea	7	8.75
Butyrospermum paradoxum	8	10
Daniellia oliveri	6	7.5
Vitellaria paradoxa	7	8.75
Total	**80**	**100.0**

Source; Field survey, 2017

4.3.0 Selected physical and chemical properties of the identified wood species

4.3.1: Physical properties of wood samples

Table 4.4 shows the summary of the physical properties of *Khaya grandifoliola, Triplochiton scleroxylon*, *Terminalia superba*, *cordia millenii* and *Gmelina arborea* used for the construction of beehives in the study area. These physical properties include; moisture content, oven-dry density, volumetric shrinkage.

The result shows that *Khaya grandifoliola* (18.7%) and *Gmelina aborea* (14.76%) had the highest and least moisture content mean value respectively. The moisture content mean values were *Khaya grandifoliola* (18.65%), *Terminalia superba* (16.31%), *Triplochiton scleroxylon (*16.26%), *Cordia millenii* (15.49%) and *Gmelina aborea* (14.76%).

The oven-dry density mean values were; *Khaya grandifoliola* (611.60kg/m^3), *Gmelina arborea* (449.83 kg/m^3), *Cordia millenii* (396.45kg/m^3) *Triplochiton scleroxylon* (395.27 kg/m^3) and *Terminalia superba (*368.5 kg/m^3*)*. The mean result of oven dry density of five wood species used for bee hives construction revealed that *Khaya grandifoliola* had the highest oven dry density (609.95±82.19%) followed by (449.83±18.32%) recorded in *Gmelina arborea* while the least oven dry density of (372.52±36.98%) was recorded in *Terminalia superba.*

The wood of *Khaya grandifoliola* (8.8%), and *Gmelina arborea (*6.2%*),* had the highest and the least mean value of volumetric shrinkage respectively. The volumetric shrinkage mean values were; *Khaya grandifoliola* (8.78%), *Triplochiton scleroxylon (8.33%) Cordia millenii* (6.31%),*Terminalia superba (*6.24%). and*Gmelina arborea (*6.21%*),*

The mean result of longitudinal shrinkage of five wood species used for beehives construction revealed that *Terminalia superba* had the highest longitudinal shrinkage (0.20±0.09%) closely followed by (0.19±0.14%) recorded in *Triplochiton scleroxylon* while the least longitudinal shrinkage of (0.15±0.09%) was recorded in *Khaya grandifoliola.*

The mean result of tangential shrinkage of wood species used for the hives construction showed that *Gmelina arborea* had the highest tangential shrinkage of

(5.38±1.33%) which was followed by (5.07±1.65%) recorded in *Khaya grandifoliola* while *Terminalia superba* had the least tangential shrinkage of (3.42±0.90%).

The result of radial shrinkage revealed that *Khaya grandifoliola* had the highest radial shrinkage of (3.71±1.49%), followed by (2.95±0.69%) recorded in *Gmelinaarborea* while *Triplochiton scleroxylon* had the least radial shrinkage of (2.23±0.82%). The result of volumetric shrinkage revealed that *Khaya grandifoliola* had the highest volumetric shrinkage (8.78±2.67%) followed by (8.33±1.31%) recorded in *Triplochiton scleroxylon* while *Gmelina arborea* had the least volumetric shrinkage (5.94±1.57%).

Table 4.4 : Summary of the physical properties of the five wood species used for the construction of bee hives

	Longitudinal shrinkage(%)	Tangential shrinkage(%)	Radial shrinkage(%)	Volumetric shrinkage(%)	Oven dry density (kg/m^3)	Moisture Content (%)
Gmelina	0.18±0.11	5.38±1.33	2.95±0.69	6.21±1.57	449.83±18.32	14.76±0.96
Cordia millenii	0.18±0.11	3.57±0.97	2.74±0.93	6.31±1.25	396.45±58.58	15.49±1.29
Triplochiton scleroxylon	0.19±0.14	3.71±1.33	2.23±0.82	8.33±1.31	395.27±29.85	16.26±2.14
Khaya grandifoliola	0.15±0.09	5.07±1.65	3.71±1.49	8.78±2.67	611.55±70.65	18.65±1.61
Terminalia superba	0.20±0.09	3.42±0.90	2.85±1.25	6.24±1.56	368.52±36.98	16.31±1.38

4.3.2 Phytochemical properties of wood samples

4.3.2.1 Alkaloids

The result of wood Alkaloids showed that *Gmelina arborea* had the highest mean value of (460.33±1.53%) in Onifuufu, followed by *Triplochiton scleroxylon* with mean value of (449.67±6.43%), while *Khaya grandifoliola* had the least mean value of (118.20±17.95%).

In Ogunmakin, *Gmelina arborea* had the highest mean value of (324.00±2.65%), followed by *Triplochiton scleroxylon*with mean value of (315.67±5.51%) while *Terminalia superba*had the least mean value of (109.00±7.81%).

The result in Adeaga shows that the highest mean value of alkaloid (435.67±3.06%) was recorded in *Gmelina arborea*, followed by *Triplochiton scleroxylon* (341.00±2.31%) with *Khaya grandifoliola* having the least mean value of (110.33±3.79%).

In Ayetoro, the highest mean value of (348.40±5.73%) was recorded in *Gmelina arborea*, followed by (325.00±6.81%) in*Khaya grandifoliola*and the least mean value was recorded in *Cordia millenii*(251.33±3.21%) (Table 4.5).

4.3.2.2 Cellulose

In Onifuufu, the result of wood Cellulose shows that *Gmelinaarborea* had the highest mean value (125.67±5.13%), and least value (62.00±2.65%) recorded in *Terminalia superba*.

In Ogunmakin, *Cordia millenii* had the highest mean value (144.33±3.79%) and the least value (65.67±2.08%) was recorded in *Gmelina arbore*a.

In Adeaga, the highest mean value of (124.00±4.00%) was recorded in *Terminalia superba* and the least mean value (90.00±2.00%) was recorded in *Gmelina arborea*.

In Ayetoro, wood cellulose had its highest mean value of (151.00±5.20%) in *Terminalia superba* and the least mean value of (113.67±5.51%) was recorded in*Khaya grandifoliola*.

4.3.2.3 Hemicellulose

In Onifuufu, the result of hemicellulose shows that *khaya grandifoliola* had the highest mean value of (185.00±1.00%) while *Triplochiton scleroxylon* had the least mean value of (82.33±2.52%).

In Ogunmakin, *Gmelina arborea* had the highest mean value of (191.00±3.61%) and the least mean value of (64.67±2.52%) was recorded in *Cordia millenii.*

In Adeaga, it was revealedthat *Triplochiton scleroxylon* had the highest mean value of(171.33±3.21%) and the least value of (73.00±3.61%) recorded in *cordia millenii*.

Finally in Ayetoro, wood hemicellulose had the highest value of (141.67±1.53%) in *Cordia millenii* and the least mean value of (100.33±3.21%) in *khaya grandifoliola*. (Table 4.5).

4.3.2.4 Cardiac

In Onifuufu, the result of wood cardiac shows that *Khaya grandifoliola* had the highest mean value of (76.67±2.08%) followed by *Terminalia superba* with mean value of (74.33±2.08%), while *Triplochiton scleroxylon* had the least mean value of (55.00±1.00%).

In Ogunmakin, *Cordia millenii* had the highest mean value of (114.00±5.29%), followed by *Gmelina arborea* with mean value of (106.33±1.53%) while *Khaya grandifoliola* had the least mean value of (72.67±2.52%).

The result in Adeaga, shows that the highest mean value of (118.33±7.57%) was recorded in *Triplochiton scleroxylon*, followed by *Khaya grandifoliola* with (112.33±2.08%), *Gmelinaarborea* recorded the least mean value of (63.67±1.53%).

In Ayetoro, the highest mean value of (114.00±2.00%) was recorded in *Triplochiton scleroxylon* followed by *Khaya grandifoliola* (95.33±3.06%) and the least mean value of (75.67±0.58%) in *Gmelina arborea*. .

4.3.2.5 Total Lignin

The result of total lignin wood shows variation among constructed hives both within the different locations and among the wood species. In Onifuufu, the highest total lignin value in wood (33.00±2.65%) was recoded in *Cordia millenii*followed by (24.33±2.08%) from *Terminalia superba*, the least total lignin value in wood samples (16.00±1.00%) was recorded in hives constructed with *Triplochiton scleroxylon* wood species.

The result of total lignin wood samples collected in Ogunmakin revealed that hives constructed with *Triplochiton scleroxylon* had the highest mean value of (16.00±1.00%), followed by (15.00±1.00%) recorded in *Terminalia superba* hives, while the least mean of (11.00±1.00%) was recorded in *Cordia millenii* hives.

In Adeaga, it was revealed that *khaya grandifoliola* had the highest value of (30.33±1.53%), followed by *Cordia millenii* with (25.67±2.08%) and *Gmelina arborea* had the least mean value of (12.33±3.21%).

The result further revealed that in Ayetoro, *Triplochiton scleroxylon* had the highest total lignin value of (36.00±2.00%) while *Cordia millenii* had the least mean value of (23.00±2.65%) in Table 4.5.

4.3.2.6 Flavonoids

The result of flavonoid in wood samples showed that *Gmelina* hives performed best in Onifuufu (277.00±12.49%) followed by *Triplochiton scleroxylon* hives (221.33±1.53%) and the least (45.33±2.00%) was recorded in *Khaya grandifoliola*.

In Ogunmakin, *Terminalia superba* hives had the highest flavonoid value (301.33±57.45%), followed by Triplochiton scleroxylon hives constructed with (75.33±1.15%) while *Khaya grandifoliola* hives (41.67±1.00%) had the least.

In Adeaga, *Gmelina* hives performed best with mean values of (277.00±2.65) followed by *Terminalia superba* (265.67 ± 2.08) and the least value of (43.67±4.36%) was recorded in *Khaya grandifoliola hives*.

In Ayetoro, *Gmelina arborea* performed best having a mean value of (72.33±1.00%) followed by *Triplochiton scleroxylon* (63.67±1.53%) while the least flavonoids value of (42.33±2.00%) was recorded in *Khaya grandifoliola* hives samples. (Table 4.5)

4.3.2.7 Phenol

In Onifuufu, the result of Phenol shows that *Terminalia superba* had the highest mean value of (66.50±0.30%), followed by *Gmelina* with mean value of (5.53±0.15%), while *Khaya grandifoliola* had the least mean value of (3.40±0.26%).

In Ogunmakin, however, *Gmelina* had the highest mean value of (66.70±0.26%), followed by *Terminalia superba* with mean Phenolic value of (59.50±0.89%) while *Triplochiton scleroxylon* had the least mean value of (21.20±0.10%).

The result in Adeaga showed that the highest mean value of (92.48±0.21%) was recorded in *Terminalia superba,* followed by *Cordia millenii* with (60.60±0.20%) while *Triplochiton scleroxylon* recorded the least mean value of (3.48±1.00%).

In Ayetoro, the highest mean value of (54.57±0.25%) was recorded in *Khaya grandifoliola*, followed by (33.50±0.40%) in *Terminalia superba* and the least mean Phenolic value was recorded in *Cordia millenii* (22.02s±0.23%) (Table 4.5).

4.3.2.8 Tannins

In Onifuufu, the result of wood tannins showed that *Terminalia superba* had the highest mean value of (854.33±14.01%), followed by *Triplochiton scleroxylon* with mean value of (234.67±0.58%), while *khaya grandifoliola* had the least mean value of (168.33±5.87%).

In Ogunmakin, *Terminalia superba* had the highest mean value of (1241.67±6.66%), followed by *Cordia millenii* with mean value of (954.00±6.93%). Hives constructed with *Gmelina arborea* had the least mean value of (130.67±1.15%).

The result in Adeaga showed that the highest mean value of (853.33±9.45) was recorded in *Terminalia superba*, followed by *khaya grandifoliola* with the value of (850.00±7.00%) and the least mean value of (23.67±1.53%) recorded in *cordia millenii*.

In Ayetoro, the highest mean value of (2253.33±10.50%) was recorded in *Terminalia superba*, followed by *Cordia millenii* (1257.33±9.45) while the least mean value of (26.00±2.65%) was recorded in *Gmelina arborea* (Table 4.8).

4.3.2.9 Saponins

In Onifuufu, the result of wood Saponin shows that *Khaya grandifoliola* had the highest mean value of (92.33±2.08%), followed by *Cordia millenii* with mean value of (72.33±2.52%), while *Triplochiton scleroxylon* had the least mean value of (61.00±1.00%).

In Ogunmakin, *Terminalia superba*had the highest mean value of (177.00±3.61%), followed by *Triplochiton scleroxylon* with mean value of (165.00±3.61%) while *Khaya grandifoliola* had the least mean value of (51.33±14.01%).

In Adeaga, the highest mean value of (81.67±1.53%) was recorded in *Gmelina arborea*, followed by *Khaya grandifoliola* with (74.33±2.08%) and *Triplochiton scleroxylon* had the least mean value of (53.67±1.53%).

In Ayetoro, the highest mean value of (205.33±6.11%) was recorded in *Terminalia Superba*, followed by *Triplochiton scleroxylon* with mean value of (174.33±2.08%), while *Khaya grandifoliola* had the least mean value of (52.67±16.29%) in Table 4.5.

Table 4.5: Chemical properties of wood samples used in the study area

Location	Wood species	Alkaloids (ppm)	Cellulose	Hemicellulose	Cardiac	Total Lignin	Flavonoid (ppm)	Phenols (µ)	Tanins	Saponin
Oyo 1	*Gmelina*	460.33±1.53	125.67±5.13	93.00±2.65	63.67±1.53	22.33±2.52	277.00±12.49	5.53±0.15	229.00±3.61	63.67±1.53
	Cordia milenni	336.68±6.11	124.00±1.00	83.00±3.61	63.00±2.65	33.00±2.65	60.67±1.15	5.27±0.15	224.33±4.51	72.33±2.52
	Triplochiton scleroxylon	449.67±6.43	123.33±3.06	82.33±2.52	55.00±1.00	16.00±1.00	221.33±1.53	4.30±0.35	234.67±0.58	61.00±1.00
	Khaya grandifoliola	118.20±17.95	73.00±3.00	185.00±1.00	76.67±2.08	23.00±2.65	45.33±0.58	3.40±0.26	168.33±5.87	92.33±2.08
	Terminalia superba	347.00±7.00	62.00±2.65	172.33±2.08	74.33±2.08	24.33±2.08	45.00±2.00	66.50±0.30	854.33±14.01	64.00±4.00
Oyo 2	*Gmelina*	324.00±2.65	65.67±2.08	191.00±3.61	106.33±1.53	12.33±2.52	71.00±2.08	66.70±0.26	130.67±1.15	83.33±3.06
	Cordia milenni	254.00±5.57	144.33±3.79	64.67±2.52	114.00±5.29	11.00±1.00	44.00±3.61	23.50±0.10	954.00±6.93	53.00±9.85
	Triplochiton scleroxylon	292.33±2.52	142.33±2.52	76.67±2.08	94.00±1.73	16.00±1.00	75.33±1.15	21.20±0.15	933.67±12.66	165.00±3.00
	Khaya grandifoliola	315.67±5.51	136.00±1.00	72.33±2.52	72.67±2.52	12.33±2.52	41.67±1.00	54.30±0.36	947.00±13.11	51.33±14.01
	Terminalia superba	109.00±7.81	92.33±2.52	66.33±1.53	82.00±2.00	15.00±1.00	301.33±57.45	59.50±0.89	1241.67±6.66	177.00±3.61
Ogun 1	*Gmelina*	435.67±3.06	90.00±2.00	73.67±3.21	63.67±1.53	12.33±3.21	277.00±2.65	60.40±0.10	136.67±2.89	81.67±1.53
	Cordia milenni	270.67±3.06	94.00±1.00	73.00±3.61	112.00±2.00	25.67±2.08	65.33±1.53	60.60±0.20	23.67±1.53	62.33±2.08
	Triplochiton scleroxylon	341.00±2.31	113.67±3.21	171.33±3.21	118.33±7.57	25.33±1.53	250.00±2.65	3.48±1.00	38.33±3.06	53.67±1.53
	Khaya grandifoliola	110.33±3.79	121.67±4.73	166.33±3.21	112.33±2.08	30.33±1.53	43.67±4.36	3.43±0.06	850.00±7.00	74.33±2.08
	Terminalia superba	293.67±14.18	124.00±4.00	166.00±6.56	83.00±2.65	25.00±2.00	265.67±2.08	92.48±0.21	853.33±9.45	72.67±4.00
Ogun 2	*Gmelina*	348.40±5. 73	123.00±4.36	105.67±6.03	75.67±0.58	25.67±1.53	72.33±1.00	22.73±0.21	26.00±2.65	56.00±2.65
	Cordia milenni	251.33±3.21	124.00±1.00	141.67±1.53	83.67±1.53	23.00±2.65	53.00±2.65	22.53±0.23	1257.33±9.45	153.00±3.61

Triplochiton scleroxylon	307.20±6.81	145.67±2.52	133.33±3.06	114.00±2.00	36.00±2.00	63.67±1.53	22.02±0.40	1257.33±12.06	174.33±2.08
Khaya grandifoliola	325.00±3.21	113.67±5.51	100.33±3.21	95.33±3.06	36.00±1.00	42.33±2.00	54.57±0.25	1127.00±18.68	52.67±16.29
Terminalia superba	275.67±17.04	151.00±5.20	132.33±2.52	84.33±1.53	31.67±1.53	53.00±4.36	33.50±0.40	2253.33±10.50	205.33±6.11

4.4 Result of proximate analysis of honey hives

4.4.1 Protein

Protein content of honey samples collected from *Gmelina arborea* hives in Onifuufu had the highest mean value of (0.60±0.10%) followed by *Khaya grandifoliola* with mean value of (0.53±0.15%). And *Terminalia superba* had the least mean value of (0.40±0.10%) protein.

In Ogunmakin, *Khaya grandifoliola* had the highest mean value of (0.63±0.21%), followed by *Cordia millenii* with (0.60±0.10%), while *Gmelina arborea* had the least mean value of (0.50±0.10%).

In Adeaga, *Khaya grandifoliola* had the highest mean value of (0.47±0.12%), followed by *Gmelina arborea* with (0.43±0.15%) and *Terminalia superba* had the least mean value of (0.33±0.15%).

In Ayetoro, the result further revealed that *Terminalia superba* had the highest mean value of (0.63±0.06%), this was followed by *Triplochiton Scleroxylon* with mean value of (0.43±0.21%) while *Cordia millenii* had the least mean value of (0.30±0.10%) in Table 4.6.

4.4.2 Carbohydrate

In Onifuufu, the result of honey carbohydrate shows that *Khaya grandifoliola* had the highest mean value of (84.23±0.21%), followed by *Cordia millenii* with mean value of (83.27±0.21%). *Terminalia superba* had the least mean carbohydrate value of (57.07±0.82%).

In Ogunmakin, the result also revealed that *Gmelina arborea* had the highest mean value of (84.43±0.21%), followed by *Terminalia superba* with (82.33±0.15%), while *Khaya grandifoliola* had the least mean value of (80.57±0.15%).

In Adeaga, *Gmelina arborea* had the highest mean value of (82.47±0.15%), closely followed by *Cordia millenii* with (82.23±0.15%) and *Triplochiton scleroxylon* had the least mean value of (81.57±0.31%). In Ayetoro, the result further revealed that *Triplochiton scleroxylon* had the highest mean value of (83.30±0.10%), followed by *Cordia millenii* with mean carbohydrate value of (82.57±0.21%) while *Terminalia superba* had the least carbohydrate value of (79.40±0.26%) in Table 4.6.

4.4.3 Ash

In Onifuufu, the result of Ash content in honey samples produced after harvesting shows that *Gmelina arborea* had the highest mean value of (0.70±0.10%) followed by *Cordia millenii* and *Triplochiton scleroxylon* with mean values of (0.50±0.10%), while *Terminalia superba* had the least mean value of (0.37±0.06%).

In Ogunmakin, *Terminalia superba* had the highest mean value of (0.63±0.15%), followed by Triplochiton *scleroxylon* with mean value of (0.53±0.06%) while *Cordia milleni* had the least mean value of (0.40±0.10%) all.

/In Adeaga, the highest mean value of (0.73±0.32) was recorded in *Cordia millenii,* closely followed by *Triplochiton scleroxylon* which recorded (0.73±0.15%) while *Khaya grandifoliola* had the least mean value of (0.33±0.06%).

In Ayetoro, the highest mean value of (0.70±0.10%) was recorded in *Khaya grandifoliola*, followed by *Cordia milleni* with mean value of (0.57±0.15),while *Gmelina arborea* and *Triplochiton scleroxylon* had the least mean values of (0.40±0.10%). in Table 4.6.

4.4.4 Sucrose

In Onifuufu, *Triplochiton scleroxylon* had the highest mean sucrose value of (7.50±0.10%) followed by *Cordia millenii* mean value of (7.33±0.15%).While *Khaya grandifoliola* had the least mean value of (4.60±0.10%).

In Ogunmakin, *Khaya grandifoliola* had the highest mean sucrose value of (6.50±0.30%), this was followed by *Triplochiton scleroxylon* with (6.43±0.21%), while *Gmelina arborea* had the least mean value of (5.47±0.42%).

In Adeaga, it was revealed that *Triplochiton scleroxylon* had the highest sucrose value of (7.33±0.21%), followed by *Terminalia superba* with (7.23±0.25%) and *Gmelina arborea* had the least mean value of (6.30±0.10%).

In Ayetoro, *Khaya grandifoliola* had the highest mean sucrose value of (4.50±0.10%), followed by *Terminalia superba* mean value of (4.43±0.12%) while *Cordia millenii* had the least mean sucrose value of (3.27±0.15%) in Table 4.6.

Table 4.6: Mean table of proxiamte analysis of honey collected from hives of wood species

Honey from hives	Wood species	Protein (%)	Carbohydrate (%)	Ash (%)	Sucrose (%)
Onifuufu	*Gmelina arborea*	0.60±0.10	82.60±0.10	0.70±0.10	7.30±0.26
	Cordia millenii	0.50±0.10	83.27±0.21	0.50±0.10	7.33±0.15
	Triplochiton scleroxylon	0.53±0.06	82.60±0.30	0.50±0.10	7.50±0.10
	Khaya grandifoliola	0.53±0.15	84.23±0.21	0.43±0.12	4.60±0.10
	Terminalia superba	0.40±0.10	57.07±0.82	0.37±0.06	4.67±0.21
Ogunmakin	*Gmelina arborea*	0.50±0.10	84.43±0.21	0.47±0.21	5.47±0.42
	Cordia millenii	0.60±0.10	81.33±0.25	0.40±0.10	6.37±0.15
	Triplochiton scleroxylon	0.53±0.12	81.33±0.15	0.53±0.06	6.43±0.21
	Khaya grandifoliola	0.63±0.21	80.57±0.15	0.47±0.15	6.50±0.30
	Terminalia superba	0.57±0.06	82.33±0.15	0.63±0.15	6.37±0.15
Adeaga	*Gmelina arborea*	0.43±0.15	82.47±0.15	0.63±0.21	6.30±0.10
	Cordia millenii	0.40±0.10	82.23±0.15	0.73±0.32	6.33±0.06
	Triplochiton scleroxylon	0.43±0.06	81.57±0.31	0.73±0.15	7.33±0.21
	Khaya grandifoliola	0.47±0.12	81.67±0.21	0.33±0.06	6.57±0.21
	Terminalia superba	0.33±0.15	81.63±0.15	0.40±0.10	7.23±0.25
Ayetoro	*Gmelina arborea*	0.43±0.15	81.37±0.25	0.40±0.10	3.33±0.15

Cordia millenii	0.30±0.10	82.57±0.21	0.57±0.15	3.27±0.15
Triplochiton scleroxylon	0.43±0.21	83.30±0.10	0.40±0.10	3.43±0.06
Khaya grandifoliola	0.33±0.06	82.47±0.31	0.70±0.10	4.50±0.10
Terminalia superba	0.63±0.06	79.40±0.26	0.50±0.10	4.43±0.12

4.5 Influence of wood species on the pattern of colonisation and abscondment of honeybees in the study area

4.5.1 Hive construction and rate of colonisation

The result on Table 4.7 revealed that *Gmelina arborea* hive had the highest colonisation rate (55.6%) followed by *Triplochiton scleroxylon*(22.2%), *Cordia millenii* (11.1%),*Terminalia superba*(8.3%) and *Khaya grandifoliola* (2.8%). Some of these problems were as a result of wrong preference of wood species for hive construction. Although there are series of factors responsible for quick colonisation of hives, but the most efficient factors are forage availability around the location of the beehives and the preference of wood species.

4.5.2 Hive construction and rate of Abscondment

The result on Table 4.8 revealed that *Khaya grandifoliola* and *Terminalia superba*(27.3%) had the highest abscondment rate followed by *Cordia millenii* and *Triplochiton scleroxylon*(18.2%) and least was *Gmelina arborea* hive (9%). The findings also relate to the 36.2% reported slow colonisation (table 4.2b). These problems is somewhat linked to the selection or preference of wood species for hives construction. Although there are series of factors responsible for quick abscondment of hives, but the most efficient factors are forage availability around the location of the beehives and the selection of wood species.

Table 4.7: Wood Hives and rate of colonisation within 7 months

Specie used for hives construction	N	Colonisation	% Colonisation
Triplochiton scleroxylon	14	8	22.2
Terminalia superba	7	3	8.3
Gmelina arborea	26	20	55.6
Cordia millenii	9	4	11.1
Khaya grandifoliola	4	1	2.8
Total	**60**	**36**	**100**

Table 4.8: Wood Hives and rate of Abscondment within 7 months

Species used for hives construction	N	Abscondment	% Abscondment
Triplochiton scleroxylon	14	2	18.2
Terminalia superba	7	3	27.3
Gmelina arborea	26	1	9
Cordia millenii	9	2	18.2
Khaya grandifoliola	4	3	27.3
Total	**60**	**11**	**100**

4.6 Mean analysis for Physical Properties of wood

Gmelina arborea hives had lowest moisture content compared to other wood species. This enhanced honeybees comb to stick together, thus, preventing abscondment of honeybees and enabled high honey yield.

Table 4.9 Mean analysis for Physical properties of wood

Wood species	Longitudinal Shrinkage (%)	Tangential Shrinkage (%)	Radial Shrinkage (%)	Volumetric Shrinkage (%)	Density (kg/m3)	Moisture Content (%)
Gmelina arborea	0.19	5.38	2.95	6.24	449.83	14.76
Cordia millennii	0.18	3.71	2.74	6.31	396.45	15.49
Triplochiton scleroxylon	0.19	3.57	2.22	8.33	395.27	16.26
Khaya grandifoliola	0.15	5.07	3.71	8.78	611.55	18.65
Terminalia superba	0.20	3.42	2.85	6.21	368.5	16.31
F-cal	**0.88**	**6.18***	**2.16**	**4.05***	**136.87***	**5.60***

Probability level is 95%

4.7 Mean analysis for Chemical Properties of wood

Gmelina arborea compared to other wood species had the highest mean for alkaloids and flavonoids and lowest cellulose, hemicellulose, cardiac, tannin and saponin means. High flavonoid in *Gmelina arborea* could be responsible for high colonisation rate of bees.

4.10 Mean Analysis for chemical properties of wood

Wood species	Alkaloids (mg/100g)	Cellulose (mg/100g)	Hemicellulose (mg/100g)	Cardiac (mg/100g)	Total Lignin (Mg/100g)	Flavonoid (mg/100g)	Tanins (mg/100g)	Saponin (mg/100g)
Gmelina arborea	392.24	101.09	115.84	77.34	18.17	174.65	130.59	71.17
Cordia millennii	278.17	121.58	90.59	93.17	23.17	55.76	614.83	135.17
Triplochiton scleroxylon	314.01	131.25	115.92	95.33	23.33	152.58	616.00	113.50
Khaya grandifoliola	217.16	111.09	130.99	89.25	25.42	45.34	773.08	167.67
Terminalia superba	272.17	107.33	134.25	80.92	24.00	166.26	1300.67	129.75
F-cal	**1.54**	**0.78**	**0.54**	**0.55**	**0.44**	**1.88**	**2.72**	**0.92**

95% probability level

4.7.1 Effect of Wood hives on asbcondment

The results of analysis of variance for colonisation indicated that location (F=1.82), did not significantly influence abscondment p> 0.05. The ANOVA result shows that there was significant difference in abscondment based on the wood species from the four locations at p< 0.05. The result of percentage abscondment rate of wood samples shows that Khaya grandifoliola and Triplochiton scleroxylon had the highest mean abscondment value of 27.30±9.05%, followed by Cordia milleini and Terminalia superba (18.20±0.00%), while Gmelina had the least mean value of 9.00±0.00% in Appendix 6.

4.7.2 Effect of Wood hives on colonisation

The results of analysis of variance for colonisation indicated that location did not significantly influence colonisation p> 0.05. However, Oyo was identified to have the highest average colonisation rates.The ANOVA result shows that there was significant difference in wood species from the four locations at p< 0.05. The result of percentage colonisation based on wood samples shows that Gmelina had the highest mean value of 84.72±13.22%, followed by Terminalia superba (54.17±35.62%) followed by Cordia millenii (43.06±33.68%), Triplochiton scleroxylon(37.50±28.54%), while Khaya grandifoliola had the least mean value of 27.78±29.59% in Appendix 7.

4.8.0 Quality of honey produced across the hives constructed with different wood species.

4.8.1 Result of Honey yield per colony (kg) based on wood samples

The result of honey yield per colony (kg) shows that Gmelina had the highest mean value of 5.91±0.97, followed by Triplochiton scleroxylon with mean value of 5.20±.11, and Cordia millenii with mean value of 5.17±0.12. Meanwhile Terminalia superba had a mean value of 4.77±0.12 and Khaya grandifoliola had the least mean value of 3.62±0.15 honey yield per colony (kg). The result of honey yield per colony (kg) revealed that Ogunmakin had the highest mean value of 5.05±0.10; this was closely followed by Adeaga with 4.98±0.11. Onifuufu had mean value of 4.93±0.11, and Ayetoro had the least mean value of 4.79±0.11 in Appendix 10.

4.8.2: Multiple regression analysis influence of Phyto-chemicals on abscondment.

There was significant influence of Phyto-chemical components of woods on abscondment rate[[F(9,10) = **8.172**, R^2 = .880; p <.05] with the variables accounting for 88% of the variance in abscondment. Further results show that cellulose(β=-.59; p<.05), hemicellulose (β=.57; p<.05), cardiac(β=.37; p<.05), total lignin (β=-.49; p<.05), phenolic(β=-.59; p<.05) and tannins(β=.49; p<.05) significantly predicted on abscondment while alkaloids (β=.02; p>.05), flavonoid (β=.09; p>.05) and saponin (β=-.24; p>.05), did not significantly influence abscondment . Table 4.12.

4.8.3: Multiple regression analysis showing influence of Phyto-chemicals on colonisation rates.

Table 4.13 shows that there was no significant joint influence of alkaloids, cellulose, hemicelluloses, cardiac, total lignin, flavonoid, phenolic, saponin and tannins on colonisation, [F(9,10) = 8.401, R^2 = .511; *p*<05] with the variables accounting for 51% of the variance in colonisation. Further results show that alkaloids (β=.52; p<.05), cellulose (β=.58; p<.05), hemicellulose(β=.42; p<.05), flavonoid (β=.60; p<.05) phenolic(β=.47; p<.05), significantly predict on colonisation while cardiac (β=.08; p>.05), total lignin(β=-.37; p>.05), tannins(β=-.61; p>.05) and saponin (β=-.70; p>.05), did not significantly influence colonisation.

4.8.4: Multiple regression analysis relationship between physical properties on abscondment rates.

Table 4.14 shows that there was a significant joint influence of longitudinal shrinkage, tangential shrinkage, radial shrinkage, volumetric shrinkage, oven-dry density and moisture on abscondment [F(9,10) = 3.666, R^2 = .767; p <.05] with the variables accounting for 77% of the variance in abscondment. Further results show that tangential shrinkage (β=.545; p<.05), radial shrinkage (β=.82; p<.05), and volumetric shrinkage (β=.51; p<.05) significantly predicted abscondment while, longitudinal shrinkage (β=.30; p>.05), oven-dry density (β=-.10; p>.05), moisture content (β=.36; p>.05) do not significantly influence abscondment.

Table 4.11 Mean Analysis for Honey samples

Wood species	Protein (%)	Carbohydrate (%)	Ash (%)	Sucrose (%)
Gmelina arborea	0.49	82.71	0.55	5.54
Cordia millennii	0.45	82.35	0.55	5.80
Triplochiton scleroxylon	0.48	82.42	0.54	6.17
Khaya grandifoliola	0.49	82.24	0.48	5.60
Terminalia superba	0.48	75.11	0.48	5.68
F-cal	0.47	5848.22*	35.67	0.88

Probability level is 95%

Table 4.12: Summary of Multiple Regression showing relationship between Phyto-chemicals and abscondment.

Predictors	B	T	P
(Constant)		6.048	<.05
Alkaloids	.015	.039	>.05
Cellulose	-.586	-5.523**	<.05
Hemicellulose	.570	-4.195**	<.05
Cardiac	.371	6.359**	<.05
Total lignin	-.485	-6.934**	<.05
Flavonoid	.091	.443	>.05
Phenolic	-.586	-4.940**	<.05
Tannins	.489	6.601**	<.05
Saponin	-.240	-.585	>.05

Table 4.13: Summary of Multiple Regression table showing influence of Phyto-chemicals on colonisation.

Predictors	B	T	P
(Constant)		8.180	<.05
Alkaloids	.519	8.551**	<.05
Cellulose	.583	8.182**	<.05
Hemicellulose	.421	6.295**	<.05
Cardiac	.077	.197	>.05
Total lignin	-.365	-.891	>.05
Flavonoid	.604	9.058**	<.05
Phenolic	.472	7.248**	<.05
Tannins	-.610	-.653	>.05
Saponin	-.701	-.688	>.05

Table 4.14: Summary of Multiple Regression table showing physical properties on abscondment.

Predictors	B	T	P
(Constant)		4.810	<.05
Longitudinal shrinkage	.301	1.392	>.05
Tangential shrinkage	.545	4.308**	<.05
Radial shrinkage	.818	4.739**	<.05
Volumetric shrinkage	.512	5.23**	<.05
Ovendry_density	-.104	-.105	>.05
Moisture	.360	1.294	>.05

4.8.5: multiple regression analysis showing the relationship between physical properties on colonisation rates.

Table 4.16 shows that there was no significant joint influence of longitudinal shrinkage, tangential shrinkage, radial shrinkage, volumetric shrinkage, oven-dry density and moisture content on colonisation [$F(9,10) = 3.180$, $R^2 = .515$; $p > 05$] with the variables accounting for 52% of the variance in colonisation. Further results show that tangential shrinkage ($\beta = -.315$; $p < .05$), radial shrinkage ($\beta = -.69$; $p < .05$), volumetric shrinkage ($\beta = .309$; $p < .05$), oven-dry density ($\beta = -.42$; $p < .05$), and moisture content ($\beta = .43$; $p < .05$) were significantly associated with colonisation rate among the honey bees. Longitudinal shrinkage ($\beta = .32$; $p > .05$) was not significant on colonisation rate among the honey bees.

Table 4.15: Summary of Multiple Regression table showing the influence of physical properties on colonisation.

Predictors	B	T	P
(Constant)		-5.092	<.05
Longitudinal shrinkage	.323	1.034	>.05
Tangential shrinkage	-.315	-4.924**	<.05
Radial shrinkage	-.687	-4.012**	<.05
Volumetric shrinkage	.309	4.639**	<.05
Oven-dry density	-.424	-3.004*	<.05
Moisture content	.432	5.075**	<.05

CHAPTER FIVE

DISCUSSION

Effects of wood species on the level of abscondment, colonisation (behaviour) and honey yield

This study focused on assessing wood species preference for beehives production, with a view to identifying potential wood species for sustainable hive habitation for improved honey production. As regards the compendium of wood species, the study initially identified fifteen (15) species of wood that were being used for bee-hive production. The following wood species were identified initially; *Gmelina arborea,* Arere (*Triplochiton scleroxylon*), Ayunre (*Albizia zygia*), Ita (*Celtis zenken*), Afara (*Terminalia superba),* Omo (*Cordia millenii*), Mahogany (*Khaya grandifoliola*), Opepe (*Nauclea diderrichii*), Ose (*Adansonia digitata*), Araba (*Ceiba pentandra*), (*Eucalyptus globulus*), (*Siamese cassia*)(*Senna siamea*), Emi (*Butyrospermum paradoxum*), Iya (*Daniellia oliveri*), Oori (*Vitex doniana, Vitex grandifolia*). This findings is similar to that of Aiyeloja and Adedeji (2014), who identified that the predominant wood families used for nesting by honeybees include: Fabaceae (11.90%), Malvaceae (19.04%) and Verbenaceae (26.19%). Further analysis revealed that the commonly used wood species by beekeepers in the selected areas were*:* *Cordia milleni* (*Cordia millenii*), Afara (*Terminalia superba*), *Gmelina arborea*, Arere (*Triplochiton scleroxylon*), and Mahogany (*Khaya grandifoliola*). And the most frequently used by the bee farmers was *Gmelina arborea* (Verbaneceae). This is in accordance with Aiyeloja and Adedeji (2014) findings, that among individual wood species, *Gmelina arborea* cavities were most encountered for bee hives followed by *Vitex doniana, Adansonia digitata* and *Anacardium occidentals*. Also, Jongjitvimol (2007) reported that honeybees significantly preferred Verbenaceae wood cavities (both living and dead) for nesting.

Analysis carried out to determine the influence of wood species on the pattern of colonisation and abscondment of honeybees in the study area, revealed that the different species had moderate rate of colonisation. Of all the wood species, *Gmelina*

arborea hive had the highest colonisation rate followed by Afara (Terminalia superba), Omo (*Cordia milleni*), Arere (*Triplochiton scleroxylon*), and Mahogany(*Khaya grandifoliola*). This colonisation rate is based on the factors responsible for quick colonisation of hives. The most efficient factors are forage availability around the location of the beehives and the types of wood species. This finding is in the same vein with Kungoza *et al.,* (2009) who discovered that the colonisation and absconding rate of honeybees' colonies were significantly influenced by hive types and location in the apiary. Findings from this study further revealed that of all the species,*Gmelinaarborea* had the highest (55.6%) rate of colonisation (Table 4.8) and least (9%) rate of abscondment (Table 4.9), thus making it to be the most suitable wood species for beehives. As a consequence, it had the highest (5.91±0.97) honey yield (Appendix 9) since high colonisation of the hive would bring about high honey production. The rate for abscondment varied from 9% for *Gmelina arborea* to 27.3% for *khaya grandifoliola* and *Triplochiton scleroxylon* .Also the rate of colonisation varied from 55.6% for *Gmelina arborea* to 2.8% for *Khaya grandifoliola.*

Relationship between physical properties of hive wood species and bee colonisation and abscondment

This study further assessed the physical properties of the wood used in beehives construction. The result revealed that *Khaya grandifoliola* had the highest mean value of moisture content while*Gmelina aborea* had the least mean value of moisture content. Low moisture content of wood is less likely to distort or warps because of its low shrinkage ability. Low moisture content is associated with stability of the hives physical properties because the woods are likely to have low shrinkage that will lead to detachment of the wax or honey combs. The most preferred woods such as *Gmelina arborea* and *Triplochitonscleroxylon* had low moisture content, thus, the durability of these wood species is high. Therefore, beeswax and honeycomb attached to the top bars tend to survive for a long period of time. White woods with high moisture content like *Khaya grandifoliola* and *Terminaliasuperba* tend to have top bars distortion leading to crack / breakup of the honeycombs and beeswax attached to the top bars. Thus, leading to the abscondment of the honeybees. This finding is similar to that of Nyau *et al.,* (2013), who found out that moisture content was significantly associated with durability of beehives and wood quality. Also, Salim *et al*., (2011) reported that

low MC was important for beehives. The moisture content of the four of the wood species were lower than that of *Anogeissus leiocapus* (17.51%) except for *Khaya grandifoliola* with mean moisture content of 18.65%. Similar trend was reported by Lausberg *et al.,* (1995); and Shupe *et al.,* (1995).

As regards wood density, this study revealed that *Khaya grandifoliola* had the highest wood density collection while *Terminalia superba* had the least density. *Gmelina aborea* had a moderate density. The variation pattern in density among the wood species could have been attributed to the anatomical structure of the woods as well as the environmental factors which varies from different state and location.

According to Leornadon *et al.,* (2009) dimensional instability is caused by H_2O absorption and often lead to large distortion making the wood. This dimensional instability of wood affect the beehives construction, foraging and colonisation activities because of its wood surface shrinkage behaviour (Yamamoto *et al,.* 2001). This study revealed that out of all the species, for tangential shrinkage, *Gmelina arborea* had the highest tangential shrinkage, while *Terminalia superba* wood had the least tangential shrinkage. For longitudinal shrinkage, *Terminalia superba* had the highest value while *Khaya grandifoliola* had the lowest longitudinal shrinkage. *Khaya grandifoliola* had the highest radial shrinkage, while *Triplochiton scleroxylon* had the lowest radial shrinkage. *Khaya grandifoliola* had the highest volumetric shrinkage, while *Gmelina arborea* had the least volumetric shrinkage. *Gmelina arborea* was the most suitable species for honeybee hives as it had lowest volumetric shrinkage, lowest moisture, lowest abscondment and high colonisation. That is, *Gmelina arborea* species was durable and this prevented water from entering the hives, leading to low abscondment of the honeybees. Also, its low moisture content prevented the wood from having high volumetric shrinkage, thus, very suitable for beehives.

Phytochemical properties of hive wood species in relation to colonisation of hives

The phytochemical analysis of wood species showed that *Gmelina arborea* had the highest alkaloid, flavonoids and phenolic. However, Arere *(Triplochiton scleroxylon*), Omo *(Cordia millenii*), Mahogany(*Khaya grandifoliola*), and Afara *(Terminalia superba)* species had higher Cellulose, total lignin compared to *Gmelina arborea*.

Flavonoids are very important to bees feeding and nesting(FAO, 2008). *Gmelina arborea* was identified to be a significant higher producer of the flavonoids useful for foraging and nesting of the African bees. High flavonoid in *Gmelina arborea* could be responsible for high colonisation rate of bees and these flavonoids were identified as good medicinal properties in recent literatures (Arora and Tamrakar, 2017).

Hives made from wood with high levels of alkaloids, cellulose and low levels of phenolic and hemicellulose had higher rate of abscondment. *Gmelina arborea* did not show these characteristics, hence, had high colonisation by honeybees. This is due to the fact that phenols and hemicelluslose contributes to the hives health of the bees. The presence of flavonoids gives a pleasant aroma to insects. There was significant influence of alkaloid, Cellulose, hemicellulose, cardiac, total lignin, phenolic on colonisation. Increasing levels of hemicellulose and phenolic substance in the wood was associated with increased colonisation. In addition decreasing levels of cellulose was associated with high colonisation.

It has been demonstrated that phytochemicals in nectar, honey, pollen, or propolis can confer other health benefits (Anderson et al, 2015). For example *p*-coumaric acid, a phenolic acid found in *Gmelina arborea* is a constituent of many honey and beehives environment. It upregulates both detoxification genes and immunity genes in larval and adult honey bees; bees consuming *p*-coumaric acid in sugar diet were capable of 60% higher rates of metabolism of the organophosphate acaricide coumaphos than bees consuming sugar diet alone (Mao *et al.,* 2013; 2015). Also, Quercetin, a flavonoid found in many honey, essentially all pollen, and in propolis in many parts of the world, also upregulates, detoxify coumaphos and enhances longevity of workers exposed to insecticide. Additionally, a sucrose diet containing both quercetin and *p*-coumaric acid enhanced the longevity of bees exposed to insecticide (Liao*et al.,* 2017).

Proximate analysis on the quality of honey in relation to wood species

As regards the quality of honey produced, 89% of the honey samples collected had moisture content less than 18.0%. Moisture content of all samples were below the maximum limit (21%) established by National Agency for Food and Drug Administration and Control, and European Union. Although there were significant differences in moisture content between honey samples obtained from the four locations. The mean moisture content (16.90±0.10%) of this study is lower than the

moisture content of the country's average (22.6%) Babatunde*et al,* (2007). According to Babatunde*et al.,* 2007, the maximum limit of moisture content of Nigerian honey so far analysed is 30%. Honey moisture content depends on the environmental conditions such as temperature, relative humidity of the area and the manipulation of honey during harvesting by beekeepers, and it can vary from season to season (Acquarone *et al.,* 2007). Moisture variability depends on climatic factors, season of production and maturity of honey (Cantarelli *et al,* 2008).

Similarly, significant difference was observed in sucrose content between honey samples collected from different locations. The amount of sucrose in honey differs according to the degree of maturity and nectar compound of the honey. Unripen honey that were harvested early contain too much sucrose (White *et al,* 1962; White, 1980; Belitz and Grosch, 1999). As the degree of ripeness increase, the amount of sucrose found in honey decreases, this indicates that the level of sucrose reduce with the maturity of honey. *Triplochiton scleroxylon* had the highest mean sucrose content while *Gmelina arborea* (5.56%) had the least mean sucrose content. This implies that *Gmelina arborea* hive had early colonisation and as such the honey samples were fully matured.

This study further revealed that the *Gmelina arborea* had the highest (0.55%) mean ash content, while *Terminalia superba* had the lowest (0.48%) mean ash content. The ash content of the honey samples analysed is lower than the maximum limits (0.6%) set for ash content of the honey by EU, CA and QSAE. Ash contents in honey could be affected by nectar ingredients for honey production (Al-Khalifa and Al-Arify, 1999; Annon, 2001-2004). The average ash content of the honey samples analysed was within the international limits for ash content of honey. This might be due to the variability of soil type and concentration of minerals found in the nectar on different apiaries. But no significant difference in ash content was observed between honey samples collected from different locations and different wood species ($p>0.05$). In general, the mean ash content (0.55%) shows that the honey is of good quality.

CHAPTER SIX

CONCLUSIONS AND RECOMENDATIONS

6.1 Conclusions

The studywasconducted to assess influence of species preference for beehive construction for effective colonisation of Honeybees in apiculture. It was generally found that *Gmelina arborea* and *Triplochiton scleroxylon* were the most preferred wood species for beehive construction in Oyo and Ogun States. It was also found that high levels of alkaloids and flavonoids in *Gmelina arborea* improved bee colonisation, reduced abscondment, and increased honey production.

The wood species used for beehive construction in Oyo and Ogun States are *Gmelina arborea*, *Terminalia superba*, *Cordia milleni*, *Triplochiton scleroxylon,Albizia zygia*, *Celtis zenken*, *Khaya grandifoliola*, *Nauclea diderichii*, *Adansonia digitata*, *Ceiba petandra*, *Eucalyptus glubulus*, *Senna siamea*, *Butyrospermum parasoxum*, *Daniellia oliveri*, and *Vitellaria paradoxa*. Only five (*Gmelina arborea*, *Terminalia superba*, *Cordia millenii*, *Triplochiton sceloroxylon,Khaya grandifoliola*) were however commonly used by beekeepers in the study area. The different wood species had moderate rate of colonisation, which was determined by forage availability around the location of the beehives and the types of wood species.

Gmelina arborea was the most suitable species for honeybee hives as it had lowest volumetric shrinkage and lowest moisture content which enhanced the durability of the hives, prevented water from entering the hives as well as enabled a long term survival of the beeswax and honeycomb attached to the top bars.It also had the highest colonisation and least abscondment rate, with resultant high honey yield.

Gmelina arborea had the highest alkaloid, flavonoids and phenolic contents. However, *Triplochiton scleroxylon*, *Cordia millenii*, *Khaya grandifoliola*, *Terminalia superba* had higher Cellulose and total lignin content. Increasing levels of hemicellulose and phenolic substance and decreasing levels of cellulose in the wood was associated with increased colonisation. *Gmelina arborea* was identified to be a significant higher producer of the flavonoids useful for foraging and nesting of the African bees.

The honey produced from all samples was of good quality. The moisture content of all samples were below the maximum limit (21%) established by National Agency for Food and Drug Administration and Control, and European Union. The average ash content of the honey samples analysed was within the international limits for ash content of honey. The sucrose content which is influenced by the degree of maturity and nectar compound of the honey differed per sample and across location. The lowest sucrose content depicting higher quality was found in *Gmelina arborea*.

6.2 Recommendations

Based on the result of the study, the following recommendations are made

- Beekeepers Association of Nigeria and all stakeholders should create awareness among beekeepers on the use of *Gmelina* for hives construction so as to increase colonisation and reduce abscondment while improving honey yield.
- Further study should be carried out to identify plants visited by bees. This will further assist in planting the appropriate plant in apiary for increased honey yield.
- Regular examination of the colony (*i.e* "Going through the bees" a phrase beekeepers use for opening the hives to examine the condition of the broods, food storage, signs and symptoms of diseases, swarming *e.t.c*) should be regularly encouraged for high yield production
- Generally, Nigerians need regular education and awareness on the importance of "genetic honeybees and trees" resources conservation. More lands need to be strictly conserved.

REFERENCES

Abrol, D.P. (1993) Insect Pollination and Crop Production in Jammu and Kashmir. *Current Science*, 65(3): 265-269.

Acquarone, C., Buera, P., and Elizalde, B. (2007). Pattern of pH and Electrical Conductivity upon Honey Dilution as a Complementary Tool for Discriminating Geographical Origin of Honeys. *Food Chemistry, 101*, 695–703.

Adedeji, G. A. and Aiyeloja, A. A. (2012) Challenges of Beekeeping in Nigeria: In Ijeomah, H. M. and Aiyeloja, A. A. (Eds.) *Challenges to Sustainable Productions in Agriculture and the Environment: Nigeria in Perspective*. Top Base Nigeria Limited, Lagos, in Conjunction with Green Canopy Consultants, Port Harcourt, Rivers State: 357-372.

Adedeji, G. A. and Aiyeloja, A. A. (2014). Preference and Suitability of Nigeria Grown Gmelina Arborea Linn.Roxb. and Vitex Doniana Sweet Woods for Beekeeping in Imeko, Nigeria. *International Journal of Scientific and Engineering Research, 5*(5), 1484-1494.

Adedeji, G. A., Aiyeloja, A. A., Larinde, S. L. and khua, G. E . (2014). Effect of Seasons on Colonisation and Suitability of Triplochiton Scleroxylon K. Schum. Wood for Beekeeping in Rivers State, Nigeria. *Natural Science, 12*(8), 117-122.

Adjare, S. O. (1990) Beekeeping in Africa. FAO Agricultural Services bulletin 68/6. Food and Agricultural Organisation of the United Nations, Rome.

Aiyeloja A. A and Adedeji G. A . (2014). Preliminary Survey of Wood Species Cavities Preferred by Honeybees in Nigeria. *International Journal of Scientific & Engineering Research, 5*(2). Retrieved from http://www.ijser.org

Akinmulewo, B. O., Oladimeji, Y. U. and Abdulsalam, Z. (2017). Assessment of the Profitability of Improved Apiculture in Federal Abuja, Nigeria. *Journal of Sustainable environment in Africa, 19*(2), 24–37.

Allen, M. & Ball, B. V. (1996). The Incidence and World Distribution of Honey Bee Viruses. *Bee World* 77:141-162.

Akyol, E., Yeninar, H., Sahinler, N. and Guler, A. (2006). The Effects of Additive Feeding and Feed Additives Before Wintering on Honeybee Colony Performances, Wintering Abilities and Survival Rates at the East Mediterranean Region. *Pakistan Journal of Biological Sciences, 9*, 589-592.

Allen, M. & Ball, B. V. (1996). The Incidence and World Distribution of Honey Bee Viruses. *Bee World* 77:141-162.

Al- Khalifa,A.S, Al - Anfy (1999). Physicochemical Characteristics and Pollen Spectrum of some Saudi Honey and Food Science and Nutrition Department, College of Agriculture, King Sand University.

Al Naggar, Y., Codling, G., Giesy, J. P., and Safer, A . (2018). Beekeeping and the Need for Pollination from an Agricultural Perspective in Egypt. *Bee World*, 1-6. doi:10.1080/0005772x.2018.1484202

Alvarez-Suarez, J.M., Gasparrini, M., Tamara, Y., Forbes-Hernández, T.Y., Mazzoni, L and Giampieri, F. (2010). The Composition and Biological Activity of Honey: A Focus on Manuka Honey. Foods, 3: 420-432.

Amdam, G.V., Simo˜es, Z.L.P., Hagen, A., Norberg, K., Schrøder, K., Mikkelsen, O. Kirkwood, T.B.L., Omholt, S.W. (2004). Hormonal Control of the Yolk PrecursorVitellogenin Regulates Immune Function and Longevity in Honeybees. *Experimental Gerontology* 39, 767–773.

Amril, A. and Ladjama, A. (2013). Physicochemical Chara-cterization of some Multifloral Honeys from Honeybees *Apis mellifera* collected in the Algerian northeast. *African Journal of Food Science* 7(7): 168 – 173.

Ande, A. T., Oyerinde, A. A. and Jibril, M. N. (2008). Comparative Study of the Influence of Hive Types on Bee Colony Establishment. *International Journal of Agriculture and Biology, 10*, 517–520.

Anderson, W.D. Jr., Johnson, G.D. & Baldwin, C.C. (2015) Review of the splendid perches, Callanthias (Percoidei: Callanthiidae). Transactions of the America Philosophical Society, 105 (Part 3), i–xxii + 1–126, pls. 1–8, figs. 1–23, tables 1–20, maps 1–5.

Amtzen, S.E. and Charles, J. (1994) Encyclopaedia of Agriculture Science. Orlando, FL Academic Press, 4:549 – 561

Arora C, and Tamrakar V. (2017)*Gmelina arborea:* Chemical constituents, Pharmacological activities and applications. International Journal of Phytomedicine **9,** 528-542.

Azeredo, L. C., Azeredo, M. A. A., Souza, S. R. and Dutra, V. M. (2003). Protein Contents and Physicochemical Properties in Honey Samples of Apis Mellifera of Different Floral Origins. *Food Chemistry, 80*, 249–254.

Babarinde, S.A., Akanbi, M.O., Akinpelu, F.A., Oyelade, B.G. and Oyelami B. (2011). Impact of Canopy Type on Honey Bee (Apis mellifera adansonii) (Hymenoptera: apidae) Colony Performance and Pest Infestation. *African Scientist, 11*(3), 169-174.

Babarinde, S.A., Odewole, A. F., Oyegoke, O. O. and Amao,O. B. (2012). Impact of Hive Dimension and Flight Entrance on Hive Colonisation, Pest Infestation and Hive Weight Gain in Apis Mellifera Adansonii (Hymenoptera: Apidae). *MunisEntCordia milennilogy and Zoology, 7*(1), 634-641.

Bailey, L. and Ball, B. V. (1991). *Honey Bee Pathology* (2nd ed.). Academic Press.

Bailey, L. & Gibbs, A. J. (1964) Acute Infection of Bees with Paralysis Virus, *J. Insect Pathol*.6, 395–407.

Babatunde, R. O., Olorunsanya, E. O., Tesho, O. A. and Alabi, B. I. (2007). Economics of Honey Production in Nigeria: Implications for Poverty Reduction and Rural Development. *Global Approaches To Extension Practice, 3*(2), 23-28.

Belitz, H.D. and Grosch, W. (1999). *Food Chemistry* (2nd ed.).

Boecking, O. and Genersch, E. (2008) Varroosis – the Ongoing Crisis in Bee Keeping. *J fu¨r Verbraucherschutz und Leb* 3: 221–228.

Bolza, E. and Keating, W. (1982) Characteristics, Properties and Uses of Timbers. South East Asia, Northern Australia and the Pacific. Inkata Press

Bowen-Walker, S. J. and Martin, A. G. (1999). The Trasmission of Deformed Wing Virus between Honeybees (Apis melliferaL) by the Ectoparasitic MiteVarroa JacobsoniOud. *Journal of Invertebrate Pathology, 73*(1), 101-106.

Brown, W.H., 1997. Introduction to Organic Chemistry. Philadelphia: Saunders College Publishing, p.113.

Burkill, H. M. (1985). The Useful Plants of West Tropical Africa. Royal Botanic Gardens.

Butler, C. G. (1967). Insect Pheromones. *Biological Reviews, 42*(1), 42-87.

CAC (Codex Alimentarius Commission), 2001: Revised standard for honey. Codex Standard 12-1981. Rev 1 (1987), Rev 2 (2001), Rome: FAO.

Cantarelli, M. A., Pellerano, R. G., Marchevsky, E. J. and Camina, J. M. (2008). Quality of Honey from Argentina: Study of Chemical Composition and Trace Elements. *The Journal of the Argentine Chemical Society, 96*(1–2), 33–41.

Caron, D.M. (1999) *Honeybee Biology and Beekeeping.* Cheshire, Conn.: Wicwas Press.

Chen, Y. P. and Siede, R. (2007). Honey Bee Virus. *Advances in Virus Research, 70*, 33-80.

Chen, Y. andEvans J. D. (2007). Historical Presence of Israeli Acute Paralysis Virus in the United States. *American Bee Journal* 147:1027-1028.

Choong, E. T. and Fogg, P. J., 1989. Effect of Cultural Treatment and Wood-Type on some Physical Properties of Longleaf and Slash Pine Wood. *Wood Fiber Sci*. 21(2):193-206.

Collins, A.M., Pettis, J.S., Wilbanks, R. & Feldlaufer, M.F. (2004) Performance of Honey Bee (Apis mellifera) Queens Reared in Beeswax Cells Impregnated with Coumaphos. *J. Apic. Res.* 43, 128–134.

Cox-Foster, D.L., Conlan, S., Holmes, E.C., Palacios, G., Evans, J.D., Moran, N.A., Quan, P.L., Briese, T., Hornig, M., Geiser, D.M., Martinson, V., Vanengelsdorp, D., Kalkstein, A.L., Drysdale, A., Hui, J., Zhai, J., Cui, L.,

Hutchison, S.K., Simons, J. F., Egolm, M., Pettis, J.S. & Lipkin, W.I. (2007) A Metagenomic Survey of Microbes in Honey Bee ColonyCollapse Disorder, *Science* 318, 283–287.

Chudnoff, M. (1984). Tropical Timbers of the World. Agriculture Handbook No. 607. United States Department of Agriculture Forest Service, Washington, DC

Croft B.A. (1990) Arthropod Biological Control Agents and Pesticides, New York, Wiley, 723 p.

De Miranda, J. R., Cordoni, G. & Budge, G. (2010). The Acute Bee Paralysis Virus-Kashmir Bee Virus-Israeli Acute Paralysis Virus Complex. *Journal of Invertebrate Pathology* 103:S30-S47.

Dinwoodie, J. M. and Desch, J. M. (1996). *Timber Structure, Properties, Conversion and Use* (7th ed.). Basingtoke: Macmillian.

Dodologlu, A., Emsen, B. and Genc, F. (2004)Comparison of someCharacteristics of Queen Honey Bees (*Apis mellifera* L.) reared by using Doolittle Method and Natural Queen Cells. *J. Applied Anim. Res*. **26**: 113-115

Du Preez, F. and Moodie, J. (2011). The History of Beekeeping In South Africa. *Bee World, 88*(2), 26–28. doi:10.1080/0005772x.2011.11417398

Duay, P., De Jong D. and Engels W. (2003) Weight Loss in Drone Pupae (*Apis mellifera*) Multiple Infested by *Varroa destructor* Mites, *Apidologie* 34, 61–65.

Duke, J. A. (1983). *Handbook of Energy Crops.* Purdue University. Retrieved from http://www.hort.purdue.edu/newcrop/duke_energy/dukeinde

Duke, J. A. (2000). Dr. Duke's Phytochemical and Ethno Botanical Database. Retrieved from http://www.arsgrin.gov/cgi-bin/duke/

Dvorak. (2005). Gastropods in Subterran Shelters of the Czech Republic. *Malacologica Bohemoslovaca, 4*, 10-16

EEA (European Environmental Agency), 2010. EU 2010 Biodiversity Baseline: Post 2010-EU Biodiversity Policy

El-Sarrag M.S.A. (1977) Morphometrical and Biological Studies on SudaneseHoneybees *Apismellifera* (Hymenoptera: (Hymenoptera: Apidae), Ph.D. Thesis, Cairo University, Egypt.

Eleazu, C.O., Iroaganachi, M. and Okoronkwo, J. (2013). Determination of the Physico-Chemical Composition, Microbial Quality and Free Radical Scavenging Activities of some Commercially Sold Honey Samples in Aba, Nigeria: The Effect of Varying Colours. *J. Nutr. Food Sci.* 3(2): 189.

Ellis, J. D. and Munn, A. P. (2005). The Worldwide Health Status of Honey Bees. *Journal Bee World, 86*(4), 88-101.

Ellis, J.D., Hepburn, R., Delaplane, K. S., Neumann, P. and Elzen, P. J. (2003). The Effects of Adult Small hive Beetles, Aethina Tumida (Coleoptera: Nitidulidae), on Nests and Flight Activity of Cape and European Honeybees (Apis mellifera). *34*(4), 399–408. doi:10.1051/apido:2003038

Erdogan, Y., Dodologluand, A. and Emsen, B(2009) Some Physiological Characteristics of Honeybee (*Apis mellifera* L.) Housed in Heated, Fan Wooden and InsulatedBeehives. Journal of Animal and Veterinary Advances 8 (8): 1516-1519.

EU Council 2002 Council Directives 2001/110/EC of 20 December 2001 Relating to Honey, Official *Journal of European communities* L10: 47-52 (2001/110/EC, EU Council 2002).

Ezeonu C. S. and Ejikeme, C. M. (2016). Qualitative and Quantitative Determination of Phytochemical Contents of Indigenous Nigerian Soft Woods. *New Journal of Science*. doi:10.1155/2016/5601327.

FAO (Food and Agriculture Organisation), 2008. Rapid Assessment of Pollinators' Status. FAO Article retrieved on 16 November, 2013 from

http://www.bfn.de/fileadmin/MDB/images/theme/bestaeuber/rapid_assessmen_polinator_status.pdf

Fasasi, K. A. (2016). Comparative Seasonal Yield of Colonies of Apis Mellifera Adansonii (Hymenoptera: Apidea) in Response to some Environmental Variables. *Journal of Entomology, 13*(1-2), 11-18.

Finley, B. L., Scott, P. K., Norton, R. L., Gargas, M.L. and Paustenbach, D. J. (1996). Urinary Chromium Concentrations in Humans Following Ingestion of Safe Doses of Hexavalent and Trivalent Chromium: Implications for Biomonitoring. J Toxicol Environ Health 48, 479-99.

Fletcher, D. J (1973) Should European Races of Honey Bees be introduced into South Africa? *South Africa Bee Journal* 45(1) 18-25

Fletcher, D. J. (1975). New Perspectives in the Causes of Absconding in the African Bee (Apis Mellifera Adansonii L.) Part I. *South African Bee Journal, 47*(6), 11-14.

Fletcher, D. J. (1978). The African Bee, Api Mellifera Adansoni, in Africa. *Annual Review, 23*, 151-171

Flottum, K. ((2010) The Backyard Beekeeper: An Absolute Beginner's Guide to Keeping Bees in Your Yard and Garden. Gloucester, Mass, Quarry Books, 2010

Fries, I (1989) Observations on the Development and Transmission of Nosema apis Z. in the Ventriculus of the Honey Bee. *Journal of Apicultural Research* 28: 107–117.

Fries, I (1993) *Nosema apis* – A Parasite in the Honey Bee Colony. Bee World 74: 5 19.

Fries, I. (1997) Protozoa. In Morse, R.A. & Flottum, K. (Eds) *Honey Bee Pests, Predators and Diseases,* A.I. Root Company; Medina, Ohio, USA; pp. 59–76 (3rd edition).

Fries, I; Feng, F (1995) Crossinfectivity of *Nosema apis* in *Apis mellifera* and *Apis cerana. Proc Apimondia 34th International Apicultural Congress.* Bucharest, Romania: 151–155.

Fries, I; Feng, F; Da Silva, A; Slemenda, S.B. and Pieniazek, N. (1996) *Nosema ceranae* n. sp. (Microspora, Nosematidae), Morphological and Molecular Characterization of a Microsporidian Parasite of the Asian Honey Bee *Apis Cerana* (Hymenoptera, Apidae). *European Journal of Protistology* 32: 356–365.

Furgala, B. and McCutcheon, D.M. (1992) Wintering Productive Colonies In: Graham, J., M., (Ed.), TheHive and the Honey bee, Dadant & Sons, Hamilton, IL.pp: 829-868.

Gibbon, P. (2001) Upgrading Primary Production: A Global Commodity Chain Approach', *World Development* 29(2): 345-363.

Griffiths, C. L. (1976): Some new and Notable Amphipoda from southern Africa. Ann. S. Afr. Mus. 61: 11–35

Groulez, J. & Wood, P. J. (1985) Terminalia superba, a Monograph. Commonwealth Forestry Institute, Oxford.

Goering, H. K., and P. J. Van Soest. (1970) Forage Fiber Analysis. USDA Agric. Handbook No. 379. USDA-ARS, Washington, DC.

Hauser, H and Lensky, Y. (1994). The Effect of the Age of the Honey Bee(Apis mellifera L) Queen on Worker Population, Swarming and Honey Yields in a Subtropical Climate. Apidologie 25(6): 566-578.

Higes, M; Martin, R; and Meana, A. (2006) Nosema Ceranae, a New Microsporidian Parasite in Honeybees in Europe. *Journal of Invertebrate Pathology* 92: 81–83

Hikino H., Kiso, Y., Wagner, H. and Fiegi, M. (1984). Antihepatotoxic Actions of Flavonoids of Flavonoligans. *Plant a Medica, 5*, 248-250.

Honey Traveler, 2012: Honey by Country Region. Honey Traveler article retrieved on 29 September, 2012 from www.honeytraveler.com/honey-bycountry-region/.

Hossain, S. A. (1999). Marketing of Egg and Broiler in Bangladesh. *World Poultry Science Association* , 56-69.

Huang, W. F., Jiang, J. H., Chen, Y.W. and Wang, C. H. (2005) Complete rRNA Sequence of the *Nosema Ceranae* from Honeybee (*Apis mellifera*). https://gra103.aca.ntu.edu.tw/gdoc/F90632004a.pdf

Hung, W. T., Chang, I. L., Hong, S. G., Young, S. D., Chen, G. W. and Lee, D. J. (1996) Floc Migration and Chemical Compositions Changes in a Freezing Chamber. J. Environ. Sci. Health.1053-1066.

International Organization for Standardization ISO 3131 (1975) Wood — Determination of Density for Physical and Mechanical tests. ISO, Geneva.

International Organization for Standardization ISO 3130 (1975) Wood Determination of Moisture Content for Physical and mechanical tests. ISO, Geneva.

International Organization for Standardization ISO 4469 (1981) Wood Determination of Radial and Tangential Shrinkage. ISO, Geneva. International Organization for Standardization ISO 4858 (1982) Wood Determination of Volumetric Shrinkage. ISO, Geneva.

IRGC, 2009 Concept Note on Risk Governance of Pollination Services. International Risk Governance Council, Geneva. Concept note retrieved 14th December, 2013 fromIRGC_Pollination_Concept_Note_2009PDF

Jenkins, R., (2009) The Effect of Manuka Honey on The Cell Cycle of Mrsa. A Doctorate Thesis submitted to University of Wales Institute Cardiff School of Applied Sciences Western Avenue, Cardiff, CF5 2YB

Johansson, T.K. (1980)*The MacMillam Family Encyclopedia*, Vol. 3. Arete Publishing Company New York

Jongjitvimol, T. & Wattanachaiyingcharoen, W. (2007) Distribution, Nesting Sites and Nest Structures of the Stingless Bee species, *Trigona collina* Smith, 1857 (Apidae, Meliponinae) in Thailand. *Natural History Journal of Chulalongkorn University*, 7, 25–34.

Julian, R. J. (1998). Rapid Growth Problems: Ascites and Skeletal Deformities in Broilers. *Poultry Science, 77*, 1773-1780.

Karlsson, T. (1990) Practical Beekeeping. *Newsl. Beekeepers Trop. Subtrop. Countries,* 17: 11-2

Kimmins, J. P. (2004) Emulating Natural Forest Disturbance: What Does this Mean? In A. H. Perera, L. J. Buse, & M. G. Weber (Eds.), Emulating Natural Forest Landscape Disturbance, Concepts and Application (pp. 8-28). New York, Columbia University Press

Kleinhenz, V., Milne, J., Walsh, K.B., Midmore, D.J. (2003) A Case Study on the Effects of Irrigation and Fertilization on Soil Water and Soil Nutrient Status, and on Growth and Yield of Bamboo (*Phyllostachys pubescens*) Shoots. Journal of Bamboo and Rattan, 2(3): 281-293.

Klemn, D., Heublein, B., Fink, H. P. and Bohn, A. (2005). Cellulose: Fascinating Biopolymer and Sustainable Raw Material. 3358-3393.

Kovac, H. and Stabentheiner, A. (2011) Thermoregulation of Foraging Honeybees Flowering Plants: Seasonal Variability and Influence of Radiative Heat Gain. *Ecol Entomol* 36, 686–699.

Kollman, F.F.P. and Cote, W.A. (1984) *Principles of Wood Science and Technology,* 1 *Solid Wood*, Springer Verlag, Berlin.

Kollman, F. F. P. and Cote, W. A. (1968) Principles of Wood Science and Technology, 1 New York: Springer-Verlag.

Kozlowski, T. T. and Pallardy, S. G. (1997) Physiology of Woody Plants, 2nd ed. San Diego, CA: Academic Press, pp.163–164.

Kugonza, D. R., Kamatara, K. B., Nabakabya, D. and Kikonyogo, S. (2009). Effects of Hive Type and Tree Shade on Colonisation Rate and Pest Prevalence of Honeybee (Apis Mellifera) Colonies in Central Uganda. *Africa Journal of Animal and Biomedical Sciences, 4*(2), 87-92.

Kumar, S., Wahab, N., Mishra, M. and Warikoo, R. (2012). Evaluation of 15 Local Plant Species as Larvicidal Agents Against an Indian Strain of Dengue Fever Mosquito, Aedes aegypti L. (Diptera: Culicidae). *Frontiers in Physiology, 3*(104). doi:doi:10.3389/fphys

Lamprecht, H., (1989). Silviculture in the TropicsTropical Forest Ecosystems and their Tree Species Possibilities and Methods for their Longterm Utilization T2Verlagsgesells chaft mbH, postatch 1164, D6101 RoBdort, Federal Republic of Germany.

Lausberg, M. J., Gilchrist, K. F. and Skipwith, H. (1995) Wood Properties of Eucalyptus Nitens Grown in New Zealand.N Z J For Sci 25(2):147-163.

Lawal, R. A., Lawal, A. K. and Adekalu, J. B. (2009). Physico-Chemical Studies on Adulteration of Honey in Nigeria. *Pakistan Journal of Biological Sciences, 12*, 1080-1084.

Leonardo, F., Caggiano, V., Rizzolatti, G. and Antonino, P. (2009) Mirror Neurons Differently Encode the Peripersonal andExtrapersonal Space of Monkeys. *Journal Science*, 324(5925) 403-406

Liao,Ling - Hsiu, W, Wen - Yen and Berenbaum, May R (2017) Impacts of Dietary Phyto Chemicals in the presence and Absence of Pesticides on Longevity of Honey Bees: *Apis mellifera Insects*, 8, 22; doi: 10.3390/ Insects 8010022

Magalhaes, F., Sousa, R. M. and Bomfim, A, I (2007) Absconding and Migratory Behaviors of Feral Africanized Honey Bee (*Apis mellifera)* Colonies in NE Brazil. *Acta Scientiarum Biological Sciences* 29(4), 381-385

Mao, Y., Zhang, H., Xu, N., Zhang, B., Gou, F. and Zhu J. K (2013) Application of the CRISPRCas System for Efficient Eenome Engineering in Plants. *Mol Plant*2008–2011.

Mao, Y., Zhang Z., Ha, S., Liu, W., Botella, J. R. and Zhu, J. K. (2015) A Multiplex CRISPR/Cas9 Platform for Fast and Efficient Editing of Multiple Genes in Arabidopsis. Plant Cell Rep http://dx.doi.org/10.1007/s00299-015-1900-z

Martin L, Dominguez J.M.L. and Bittencourt, A.C. (1998) Climatic Control of Coastal Erosion During a Sea-Level Fall Episode. *An Acad Bras Ci* 70**:** 249-266.

Monheim, S. G., Meixner, M., Liebig, G. and Rosenkranz, P. (2010). The German Bee Monitoring Project: a Long Term Study to Understand Periodically High Winter Losses of Honey Bee Colonies. *Apidologie*. doi:10.1051 /apid /apido/2010014:

Morse, D. H. (2007) *Predator upon a Flower: Life History and Fitness in a Crab Spider*, Cambridge, MA: Harvard University Press

Morse, R. A. and Hooper, T(1986) The Illustrated Encyclopaedia of Beekeeping, New York: Dutton

Morse R. A. and Calderone, N. W. (2000). The Values of Honeybees as Pollinators of US Crops. *Cornell University*. Retrieved from http://www.masterbeekeeper.org/pdf/pollination.pdf

Morse, R.A. & Flottum, K.(1997) *Honey Bee Pests, Predators and Diseases,* A.I. Root Company; Medina, Ohio, USA; pp. 59–76 (3rd edition).

Muthukumaran P., Saraswathy N., Aswitha V., Balan R., Gokhul V. B., Indumathi P. and Yuvapriya, S . (2016). Assessment of Total Phenolic, Flavonoid, Tanning Content and Phytochemical Screening of Leaf and Flower extracts from Peltophorum Ptero Carpum (DC.) Backer ex K.Heyne: a Comparative Study.

Neumann, P., Pettis, J. S. and Schäfer, M. O. (2016). Quo vadis Aethina Tumida? Biology and Control of Small Hive Beetles. *Apidologie, 47*(3), 427–466. doi:10.1007/s13592-016-0426-x

Nyau, V., Mwanza, P. and Moonga, B. (2013). Physicochemical Qualities of Honey Harvested from Different Beehive Types in Zambia. *African Journal of Food Agric.Nutritionand Development,* 13(2): 7415-7427.

Ofori, J., 2004b. Master of Science Lecture Notes on WST 525-2: Wood-Moisture Relationships, Department of Science and Technology, FRNR-KNUST. (Unpublished). Pp 1-11

Ogbonnaya, C. I, Nwalozie, M. C. and Nwaigbo, L. C. (1992). Growth and Wood Properties of Gmelina arborea (Verbenaceae) Seedings Grown under Five Soil Moisture Regime. *American Journal of Botany, 79*(2), 128-132.

Okwee-Acai, J., Anyanzo, T. A., Aroba, J., Vuchiri, J. K., Onzivua, T. and Okullo, P. (2010). Effects of Apiary Management on Colonisation and Colony Performance of African Honey Bee (Apis mellifera) in the North-Western Agro-Ecological Zone of Uganda. *Livestock Research for Rural Development*. Retrieved from http://www.lrrd.org/lrrd22/5/okwe22086.htm.

Olagunju, D. (2000)*Alleviating Poverty Through Beekeeping*, p: 189. Charli-Tonia Publisher Osogbo, Nigeria.

Oyerinde, A. A. and Ande, A. T. (2009). Distribution and Impact of Honeybee Pests on Colony Development in Kwara State, Nigeria. *Journal of Agriculture and Social Sciences, 5*(3), 85 – 88.

Panshin, A.J. and De Zeeuw, C. (1980)*Textbook of Wood Technology: Structure, Identification, Properties, and Uses of the Commercial Woods of the United States and Canad*a. McGraw-Hill Book Co., New York.

Peng, C. Y. and So, T. S. H. (2002). Modeling strategies in logistic regression. *Journal of Modern Applied Statistical Methods, 14,* 147–156.

Posho Ndola, B., Malumba, P., Wathelet, B., Haubruge, E., Francis, F., and Nguyen, B. K. (2017). Assessment of Nutritional Resources Quality from Honeybees (Apis mellifera adansonii, L. 1758: Hymenoptera, Apidae) in Three

Beekeeping sites of the Democratic Republic of Congo. *International Journal of Biological and Chemical Sciences, 11*(2). doi:10.4314/ijbcs.v11i2.2

Rao, P. V., Krishnan, K. T., Salleh, N. and Gan, S. H. (2016). Biological and Therapeutic Effects of Honey Produced by Honeybees and Stingless Bees: a Comparative Review. *Revista Brasileira de Farmacognosia, 26*(5), 657–664. doi:10.1016/j.bjp.2016.01.012

Rosenkranz, P., Monheim, S. G., Meixner, M. and Liebig, G. (2010). The German Bee Monitoring Project: a Long Term Study to Understand Periodically High Winter Losses of Honey Bee Colonies. *Apidologie*. doi:10.1051 /apid /apido/2010014:

Sahle, H., Enbiyale, G., Negash, A. and Neges, T. (2018) Assessment of HoneyProduction System, Constraints and Opportunities in Ethiopia. Pharmacy and Pharmacology of International Journal, 6(2): 2379- 6367.

Salim, A. B., Zohair, A., Hegazy, A. E. and Said, A. (2011). Effect of some Strains of Probiotic Bacteria against Toxicity Induced by Aflatoxins. *Journal of American Science,* **7**(1): 772-783.

Sathishkumar, T., Baskar, R., Aravind, M., Tilak, S., Deepthi, S. and Bharathikumar, V.M. (2013). Simultaneous Extraction, Optimization and Analysis of Flavonoids from the Flowers of Tabernaemontana Heyneana by High Performance Liquid Chromatography Coupled to Diode Array Detector and Electrospray Ionization/mass Spectrometry. Biotechnology. doi:10.5402/2013/450948

Scheffer, T. C. and Morrell, J. J. (1998) Natural Durability of Wood: A Worldwid Checklist of Species. Research Contribution 22. Forest Research Laboratory, Oregon State University, Corvallis. 58 pp.

Schneider, B. (1990). The Climate for Service: An Application of the Climate Construct. In B. Schneider (Ed.), *OrganizationalClimate and Culture* (pp. 383—412). San Francisco: Jossey-Bass.

Siede, R., Konig, M., Buchler, R., Failing, K. & Thiel, H. J. (2008). A Real-Time PCR Based Survey on Acute Bee Paralysis Virus in German Bee Colonies. *Apidologie (Celle)* 39, 650–661.

Siepe, A. and Haussler, D. (2004) Combining Phylogenetic and Hidden Markov Models inBiosequence Analysis. *Journal of Computational Biology*, 11, 413–428.

Sjostrom, E. (1993). Introduction to carbohydrate chemistry, in: *Wood Chemistry (Second Edition)*, Academic Press, San Diego, USA, 21-50.

Shamsa, F., Monsef, H., Ghamooshi, R. and Verdian-riz, M. (2008). Spectrophotometric Determination of Total Alkaloids in some Iranian Medicinal Plants. *Thai J. Pharm. Sci, 32*, 17-20.

Shen M., Yang X., Cox-Foster D., & Cui L. (2005b). The Role of Varroa Mites in Infections of Kashmir Bee Virus (KBV) and Deformed Wing Virus (DWV) in Honeybees. *Virology*342(1):141-149.

Shimanuki, H., Calderone, N.W., Knox, D.A., (1994) Parasitic Mite Syndrome: the Symptoms. *Am. Bee J.* 134, 827–828.

Shupe, T.F; Choog, E.T. and Gibson, M.D. (1995b). Differences in Moisture Content and Shrinkage between Inner Wood and Outer Wood of a Single Cotton Wood Tree. Forest Products Journal 45 (10): 89 - 92.

Siede R. and Buchler R. (2004). First Detection of Kashmir Bee Virus in Hesse (German). *Berliner und Munchener Tierarztliche Wochenschrift* 117:12-15.

Smith, F. (1960). *Beekeeping in the Tropics.* Bristol: Longmans.

Spiewok, S., Neumann, P. and Hepburn, H. R. (2006). Preparation for Disturbance-Induced Absconding of Cape Honeybee Colonies (Apis mellifera Capensis Esch). *Insectes Sociaux, 53*(1), 27–31. doi:10.1007/s00040-005-0829-6

Spivak, M. and Reuter, G. S. (1997) *Successful Queen Rearing*. University of Minnesota, St. Pauls, Minnesota

Stamm. A. J.(1964) Wood and Cellulose Science. Ronald Press. New York. NY.

Stamm. A. J. (1971). Maximum Effective Pore Sizes of Nuclepore Membrane Filters. *Tappi, 54*

Standifer, L. N.(2007). Honey Bee Nutrition and Supplemental Feeding. Excerpted from Beekeeping in United States.

Starks, P. T., Blackie, C.A.and Seeley T. D. (2000) Fever in Honey Bee Colonies. Naturwissenschaften 87:229–231.

Sukumar, K., Perich, M. and Boobar, L. (1991). Botanical Derivatives in Mosquito Control: A Review. *Journal of American Mosquito Control Assoc, 7*, 210-237.

Tanz, S. K., Castleden, L., Hooper, C., Vacher, M., Small, I. and Millar, H. (2013). SUBA3: A Database for Integrating Experimentation and Prediction to Define the SUBcellular Location of Proteins in Arabidopsis. *Nucleic Acids Research, 41*, 1185–1191. doi:10.1093/nar/gks1151

Taylor, O. R. and Spivak, M. (1984). Climatic Limits of Tropical African Honeybees in the American Bee. *World Monument, 65*, 38-47.

Taylor M. A., Goodwin R. M., McBrydie, H. M., Cox, H. M. (2007) Destroying Managed and Feral Honey bee (Apis mellifera) Colonies to Eradicate Honey Bee Pests. *New Zeal J Crop Hortic Sci* 35: 313–323.

Tirado, R. and Johnson, P. (2013). Bees in Decline: A Review of Factors that Put Pollinators and Agriculture in Europe at Risk.*Greenpeace International.*

Tessega Belie, 2009. Honeybee Production and Marketing Systems, Constraints and Opportunities In Burie District of Amhara Region, Ethiopia. Ethiopia. MSc Thesis Presented to the School of Graduate Studies of Bahir Dar University. Pp.131

Tsegay., Gebreegiziabher, Z. and Mesfin, T. (2017). Opportunities and constraints of Beekeeping in Wolaita and Dawro zones, Southern Ethiopia. *African Journal of Agricultural Research, 12*(18), 1587–1592. doi:10.5897/ajar 2017.12233

UNEP. 2010. Global Honey Bee Colony Disorder and other Threats to Insect Pollinators. UNEP Emerging Issues retrieved on 16 November, 2013 from www.unep.org/dewa/Portals/67/pdf/Globalbee_colony_disorder_and_threats_ nsects pollinators.pdf.

White J.W. 1960. HydroxymethylFurfural Content of Honey as an Indicator of its Adulteration with Invert Sugars. *Bee World*, *61* (1), 29-37.

White J. W., Riethof M. L., Subers, M. H. and Kushnir, J. (1962) Composition of American Honey. Tech Bull U.S. Dep Agric, 1261-124 A.A. 655/53

White, J. W, Riethof, M. L, Subers M. H. and Kushnir J. (1962) Composition of American Honey. Tech Bull U.S. Dep Agric, 1261-124 A.A. 655/53

White, W. A. (2011). Financial Benefits of Box Hive and the Determinants of Its Adoption in Selected District of Ethiopia. *American Journal of Economics, 1*(1), 21-29. doi:10.5923/j.economics.20110101.03

White, W. J. (1980). Hydroxymethyl Furfural Content of Honey as an Indicator of its Adulteration with Invert Sugars. *Bee World, 61*(1), 29-37

Wineman, E., Lensky, Y. and Mahrer, Y. (2003): Solar Heating of Honey Bee Colonies (*Apis mellifera* L.) during the Subtropical Winter and its Impact on Hive Temperature, Worker Population and Honey Production. Amer. Bee J., 143(7): 565-570.

Winston, F., Chumley, F. and Fink, G. R. (1983). Eviction and Transplacement of Mutant Genes in Yeast. Meth. Enzymol. In press.

Winston, M. L. (1987). The Biology of the Honey Bee. Harvard University Press, Cambridge.

Winston, M. L. (1992). The Biology and Management of Africanized Honey Bees. *Ann Rev Entomol, 37*, 173-193.

Winston M.L. 2003. *A biologia da abelha.* Porto Alegre: Magister, 2003

Wok, A. I. (2018). Annual Honey Report . Retrieved from https://www.beeculture.com/2018-annual-honey-report

Workneh A.W., Puskur, R. and Karippai, R. S. (2008) Adopting improved Box Hive in Atsbi Wemberta district of Eastern Zone, Tigray Region: Determinants and Financial benefits. IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working Paper 10. ILRI (International Livestock Research Institute), Nairobi, Kenya. 30 pp.

Workneh A. W. (2011) Financial Benefits of Box Hive and the Determinants of Its Adoption in Selected District of Ethiopia. *American Journal of Economics*, *1* (1), 21-29. doi: 10.5923/j.economics.20110101.03.

Yamamoto, M., Kayanne, H., Yamamuro, M., 2001. Characteristics of Organic Matter in Lagoonal Sediments from the Great Barrier Reef. Geochem. J. 35, 385- 401.

Yang, X. and Cox-Foster, D. (2005). Impact of an Ectoparasite on the Immunity and Pathology of Invertebrate: Evidence for Host Immunosuppression and Viral Amplification. *Proceedings of the National Academy of Science of the United States of America*, *102*, pp. 7470-7475.

Yue, C. and Genersch, E. (2005). RT-PCR Analysis of Deformed Wing Virus in Honeybees (Apis Melilifera) and Mites (Varroa Destructor). *Journal of General Virology, 86*(12)

Yue, C., Schröder, M., Gisder. S. & Genersch, E. (2007) Vertical-Transmission Routes for Deformed Wing Virus of Honeybees (Apis mellifera). *J. Gen. Virol*. 88, 2329–2336

Yue, C., Schröder, M., Bienefeld, K.&Genersch, E. (2006) Detection of Viral Sequences in Semen of Honeybees (Apis mellifera): Evidence for Vertical Transmission of Viruses through Drones. *J. Invertebr. Pathol*. 92, 93–96

Zobel, B.J. and Jett, J.B. (1995) Genetics of Wood Production. Berlin: Springer, 369p.

Zhang, S.Y. & Zhong, Y(1992) Structure-Property Relationships of Woods in East Liaoning oak.*Wood Sci. Technol*. 26:139–149.

APPENDICES

Appendix 1: Questionnaire

UNIVERSITY OF IBADAN, IBADAN

DEPARTMENT OF FOREST RESOURCES MANAGEMNT

WOOD SPECIES SELECTIVITY FOR BEEHIVE PRODUCTION IN OYO AND OGUN STATES KEY INFORMANT QUESTIONNAIRE

Preamble:

This questionnaire is designed for the purpose of studying the wood species selected for beehive production in South West Nigeria. You are kindly requested to provide correct answers to the questions. The research is purely academic and has nothing to do with taxation. You are assured of the strict confidentiality of the information provided.

Thank you for your cooperation

Akinlade A.A.S

1. Name of State----------
2. Name of the Community……
3. Age of respondent in years……(a) Less than 30 (b) 30-39 (c)
4. Sex (a) Male ☐ (b) Female ☐
5. Education background of the respondent (a) Primary ☐ Secondary ☐ (c) Post-Secondary ☐ (d) No formal education ☐
6. How long have you been residing in the community. (a) Between 1-5 years ☐ (b) Between 5 -10 years ☐ (c) Between 10 – 15 years ☐ (d) between 15 - ☐ 20 years ☐ (e) Above 20 years
7. Number of housing unit (approximate): ……..
8. Ethnic group (a) Yoruba (b) Hausa (c) Igbo (d) Others
9. Religion: (a) Christianity (b) Islam(c) Traditional (d) Others
10.

Compendium of wood species used for beekeeping

11. Which type of wood did you use for your hive construction (a) White Wood (b)
12. What is the name of the wood used for your hive construction? _____
13. How many hives do you have (a) 1-5 (b) 6-10 (c) 11-15 (d) Above 15
14. What is the main use of the produce from this bee rearing? _____

15. Do you encounter any problem with your beehives? (a) Yes, (b) No
16. if yes, what problem is it? (a) Colonisation (b) Disturbance by external bodies (c) theft (d) others, specify…….
17. What do you think caused the problem? (a) Types of wood (b) Weather condition (c) Others specify…….
18. Do bees colonize your hives fast? (a) Yes (b) No,
19. If yes, What factor (s) do you think is responsible for the quick colonisation _____
20. When did you start beekeeping (Years of beekeeping experience)? (a) Below 5 years. (b) 6-10years. (c) 11-15 years. (b) 16-20years. (e) Above 20 years
21. Total production of honey (kilograms)

Where do you keep your bee colonies?

No	**Site or placement of hive**	**Traditional**	**Intermediate**	**Movable-frame**
1	Backyard			
2	Under the roof			
3	Inside the house			
4	Hanging on trees near homestead			

22. Do you have empty beehives? 1. Yes ___ 2. No___
23. If yes, list the number of empty hives you have.

No	Types of beehives	Numbers	Reasons (use causes in question 30)
1	Traditional		
2	Intermediate		
3	Movable-frame		

24. Is there an increase in trend in number of bee colonies and honey yield over the last 5 years, (a) yes, (b) No
25. If yes what are the causes? _____
26. Did your colonies abscond? (a). Yes_____ (B). No____
27. What are the reasons for bees absconding hive? _____
28. What measures do you undertake to prevent absconding? _____
29. Do you observe any honeybee diseases in your apiary? 1. Yes____ 2.No____

30. If yes, what are the diseases you observed?

No	Local name	Stages of bee affected	Symptoms	Incidence period	Local control measure/s
Adult	Brood				
1					
2					
3					

iv. Colony Management and Honey harvesting

32. Do you visit and inspect your beehives and colonies? (a). Yes____(b).No_____

33. If yes, which type of inspection do you perform? _____

34. Frequency of inspection (a). frequently (b). sometimes(c). rarely

35. If no inspection, what is the reason?

36. Do you clean your apiary? 1. Yes_____ 2. No_____

Post-Harvest Management

37. Do you strain your honey? ?(a). Yes____(b). No_____

38. If yes, what materials do you use for straining?_____

39. If you don't strain your honey why?_____

40. For how long do you store your honey? _____

41. Why do you store honey? _____

42. If your honey is crystallized, did you change it to viscous honey? (a). Yes. (b)No__

43. If yes, what methods do you use? _____

44. What are the factors that govern the price of the honey in your locality? Describe How? _____

45. Who are your customers? (a). Middlemen (b). Retailers (c).Wholesalers (d). Consumers (e).co-operative (f).others specify:_____

46. Where do you sell your honey? _____

47. Which honey command greater market value? _____

VIII. Beekeeping extension

48. Do you have contact with extension agent? (a). Yes (b). No

49. Who assisted you in improving your beekeeping production activities? (a).Agricultural and Rural development (b).Non-Governmental Organization(c).Research Centre (d).Neighbour(e). Relatives (f).Othersspecify _____

50. Which extension media helped you most to learn about beekeeping? _____

51. In what area were you trained? _____

52. Can you practically apply the training? (a). Yes (b). No

53. If no, what was wrong with the training? _____

Appendix 2: Analysis of variance for physical properties of wood samples

Property	SV	SS	df	MS	F.	Sig.
longitudinal thickness	Wood species	4.05	4	1.01	23.18	0.00*
	Location	0.97	3	0.32	7.41	0.00*
	Spp*Location	1.59	12	0.13	3.03	0.00*
	Error	16.61	40	0.04		
	Total	106.36	42			
tangential thickness	Location	890.87	4	222.71	123.85	0.00*
	Wood species	62.82	3	20.94	11.64	0.00*
	Location*Wood	213.99	12	17.83	9.92	0.00*
	Error	683.35	380	1.798		
	Total	14733.99	400			
Radial thickness	Location	160.51	4	40.13	31.65	0.00*
	Wood species	1.04	3	0.35	0.27	0.85^{ns}
	Location*Wood	30.15	12	2.51	1.98	0.02*
	Error	481.81	40	1.27		
	Total	5962.07	42			
Volumetric thickness	Location	1786.34	4	446.58	159.89	0.00*
	Wood species	64.86	3	21.62	7.74	0.00*
	Location*Wood	242.49	12	20.21	7.24	0.00*
	Error	1061.33	40	2.79		
	Total	37834.98	42			
Longitudinal shrinkage	Location	0.13	4	0.03	1.78	0.13^{ns}
	Wood species	0.03	3	0.00	0.46	0.71^{ns}
	Location*Wood	0.59	12	0.05	2.63	0.00*
	Error	7.09	40	0.02		
	Total	20.88	42			
Tangential shrinkage	Location	270.69	4	67.67	54.84	0.00*
	Wood species	75.36	3	25.12	20.36	0.00*
	Location*Wood	88.059	12	7.338	5.95	0.00*
	Error	468.937	40	1.234		
	Total	8059.78	42			
Radial shrinkage	Location	90.89	4	22.72	28.70	0.00*
	Wood species	9.19	3	3.06	3.87	0.01*
	Location*Wood	150.40	12	12.53	15.83	0.00*
	Error	300.84	40	0.79		
	Total	3906.43	42			
Volumetric shrinkage	Location	558.48	4	139.62	76.78	0.00*
	Wood species	136.45	3	45.48	25.01	0.00*
	Location*Wood	381.27	12	31.77	17.47	0.00*
	Error	691.00	40	1.82		
	Total	22079.37	42			
Oven-Dry Density(%)	Location	2985032	4	7462.58	305.75	0.00*
	Wood species	18249.75	3	6083.2	2.49	0.06^{ns}

	Location*Wood	64145.17	12	5345.43	2.19	0.01*
	Error	927473	40	2440.72		
	Total	83135.50	42			
Moisture Content(%)	Location	629.68	4	157.42	118.56	0.00*
	Wood species	182.94	3	60.98	45.93	0.00*
	Location*Wood	237.40	12	19.78	14.89	0.00*
	Error	504.56	40	1.323		
	Total	10836.03	42			

*Significant and ^{ns} Not Significant at 5% probability level

Appendix 3: Analysis of variance of chemical properties of wood samples

Property	SV	Df	SS	MS	F-cal	F-tab
Alkaloids(mg/100)	Location	3	33963.17	11321.04	55.609*	2.84
	Wood species	4	56939.90	14234.98	69.922*	2.61
	Location*Wood	12	483128.63	40260.72	197.760*	1.95
	Error	40	8143.33	203.58		
	Total	42	582174.98			
Tanins (mg/100g)	Location	3	12316385.13	4105461.71	17287.368*	2.84
	Wood species	4	1450652.10	362663.03	1527.109*	2.61
	Location*Wood	12	6317075.37	526422.95	2216.673*	1.95
	Error	40	9499.33	237.48		
	Total	42	20093611.93			
Cardiac (mg/100g)	Location	3	8940.13	2980.04	382.057*	2.84
	Wood species	4	2913.43	728.36	93.379*	2.61
	Location*Wood	12	10788.03	899.00	115.257*	1.95
	Error	40	312.00	7.80		
	Total	42	22953.60			
Saponins (mg/100g)	Location	3	174338.32	58112.77	1657.208*	2.84
	Wood species	4	26172.10	6543.03	186.588*	2.61
	Location*Wood	12	101547.77	8462.31	241.321*	1.95
	Error	40	1402.67	35.07		
	Total	42	303460.85			
Cellulose (mg/100g)	Location	3	7364.53	2454.84	220.826*	2.84
	Wood species	4	6885.27	1721.32	154.841*	2.61
	Location*Wood	12	25962.47	2163.54	194.621*	1.95
	Error	40	444.67	11.12		
	Total	42	40656.93			
Hemicellulose (mg/100g)	Location	3	11388.58	3796.19	352.043*	2.84
	Wood species	4	14311.23	3577.81	331.791*	2.61
	Location*Wood	12	88705.83	7392.15	685.516*	1.95
	Error	40	431.33	10.78		
	Total	42	114836.98			
Total Lignin	Location	3	2252.05	750.68	184.55*	2.84
	Wood species	4	362.07	90.52	22.258*	2.61
	Location*Wood	12	1104.20	92.02	22.627*	1.95
	Error	40	162.67	4.07		
	Total	42	3880.98			
Flavonoid (mg/100g)	Location	3	400067.65	133355.88	749.82*	2.84
	Wood species	4	34531.90	8632.98	48.54*	2.61
	Location*Wood	12	135638.10	11303.18	63.56*	1.95

	Error	40	7114.00	177.85		
	Total	42	577351.65			
Phenolic	Location	3	1528.47	509.49	2469.86*	2.84
	Wood species	4	7531.05	1882.76	12822.44*	2.61
	Location*Wood	12	27402.32	2283.53	15551.83*	1.95
	Error	40	5.87	0.147		
	Total	42	36467.71			

*Significant **Not significant at 5% probability level

Appendix 4: Analysis of variance for Honey samples

Property	SV	Df	SS	MS	F-cal	F-tab
Moisture content (%)	Location	3	41.25	13.8	74.19*	2.84
	Wood species	4	3.38	0.85	4.57*	2.61
	Location*Wood	12	26.52	2.21	11.93*	1.95
	Error	40	7.41	0.19		
	Total	59	78.57			
Protein (%)	Location	3	0.04	0.01	0.83^{ns}	2.84
	Wood species	4	0.06	0.02	0.93^{ns}	2.61
	Location*Wood	12	0.26	0.02	1.38^{ns}	1.95
	Error	40	0.63	0.02		
	Total	59	0.99			
Viscosity (Centistokes) (t*4.697)	Location	3	45420.13	15140.04	215.01*	2.84
	Wood species	4	25886.10	6471.53	91.90*	2.61
	Location*Wood	12	189098.03	15758.17	223.79*	1.95
	Error	40	2816.65	70.42		
	Total	59	263220.93			
Ash (%)	Location	3	0.05	0.02	0.76^{ns}	2.84
	Wood species	4	0.07	0.02	0.85^{ns}	2.61
	Location*Wood	12	0.83	0.07	3.49*	1.95
	Error	40	0.79	0.02		
	Total	42	1.74			
Carbohydrates (By difference %)	Location	3	24.80	8.27	125.91*	2.84
	Wood species	4	9.73	2.43	37.06*	2.61
	Location*Wood	12	53.02	4.42	67.29*	1.95
	Error	40	2.63	0.07		
	Total	42	90.19			
Sucrose (%)	Location	3	80.14	26.71	715.53*	2.84
	Wood species	4	3.08	0.77	19.25*	2.61
	Location*Wood	12	33.84	2.82	75.55*	1.95
	Error	40	1.49	0.04		
	Total	42	118.56			
Terpernoid	Location	3	81314.58	27104.86	3176.35*	2.84
	Wood species	4	5704.77	1426.19	167.13*	2.61
	Location*Wood	12	54589.50	4549.13	533.10*	1.95
	Error	40	341.33	8.53		
	Total	59	141950.18			

*Significant and ^{ns}Not Significant at 5% probability level

Appendix 5: Total mean table of phytochemical properties of honey bees

	Terpenoids	Carbohydrate	Protein	Viscosity	Ash	Sucrose
Gmelina	90.58±3.03	82.72±0.18	0.49±0.13	2428.92±8.39	0.55±0.16	5.60±0.23
Cordia Millenii	85.17±2.61	82.35±0.21	0.45±0.13	2459.75±7.45	0.55±0.17	5.83±0.13
Triplochiton Scleroxylon	109.42±2.41	82.20±0.22	0.48±0.11	2477.67±4.90	0.54±0.10	6.17±0.15
Khaya grandifoliola	99.17±3.48	82.24±0.22	0.49±0.14	2463.42±10.32	0.48±0.11	5.54±0.18
Terminalia Superba	109.25±2.31	75.11±0.35	0.48±0.09	2503.83±11.67	0.48±0.10	5.68±0.18

Appendix 6 : Wood for Hives construction and rate of Abscondment

	N	Mean % abscondment	S. D
Terminalia superba	4	33.3000[b]	.00000
Triplochiton scleroxylon	4	24.9750[a]	16.65000
Gmelina	4	8.3250[a]	16.65000
Khaya grandifoliola	4	49.8000[b]	19.05413
Cordia millenii	4	33.3000[b]	.00000
Total	20	29.9400	18.33597

Appendix 7 : Effect of wood hives on colonisation

	Ogun 1		Ogun2		Oyo2		Oyo1		Overall	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Terminalia superba	72.22	25.46	44.44	41.94	50.00	44.10	50.00	44.10	54.17[b]	35.62
Triplochiton scleroxylon	33.33	28.87	38.89	34.69	38.89	34.69	38.89	34.69	37.50[a]	28.54
Gmelina	83.33	16.67	83.33	16.67	94.44	9.62	77.78	9.62	84.72[c]	13.22
Khaya grandifoliola	38.89	34.69	16.67	28.87	16.67	28.87	38.89	34.69	27.78[a]	29.59
Cordia millenii	44.44	41.94	38.89	34.69	50.00	44.10	38.89	34.69	43.06[b]	33.68
Total	54.44	33.01	44.44	35.45	50.00	39.34	48.89	32.41	49.44	34.44

Appendix 8: Effect of wood hives on colonisation (%)

		Average number of Top bar colonised		% percentage colonisation	
Location	Wood species	Mean	S.D	Mean	S.D
Onifuufu	*Terminalia superba*	2.67	2.52	50.00	44.10
	Triplochiton scleroxylon	2.33	2.08	38.89	34.69
	Gmelina	5.00s	1.00	77.78	9.62
	Khaya grandifoliola	1.00	1.73	38.89	34.69
	Cordia millenii	2.33	2.08	38.89	34.69
	Total	2.67	2.13	48.89	32.41
Ogunmakin	*Terminalia superba*	4.33	1.53	50.00	44.10
	Triplochiton scleroxylon	2.00	1.73	38.89	34.69
	Gmelina	5.33	1.53	94.44	9.62
	Khaya grandifoliola	2.33	2.08	16.67	28.87
	Cordia millenii	2.67	2.52	50.00	44.10
	Total	3.33	2.09	50.00	39.34
Adeaga	*Terminalia superba*	3.00	2.65	72.22	25.46
	Triplochiton scleroxylon	2.33	2.08	33.33	28.87
	Gmelina	5.67	0.58	83.33	16.67
	Khaya grandifoliola	1.00	1.73	38.89	34.69
	Cordia millenii	3.00	2.65	44.44	41.94
	Total	3.00	2.36	54.44	33.01
Ayetoro	*Terminalia superba*	3.00	2.65	44.44	41.94
	Triplochiton scleroxylon	2.33	2.08	38.89	34.69
	Gmelina	4.67	0.58	83.33	16.67
	Khaya grandifoliola	2.33	2.08	16.67	28.87
	Cordia millennii	2.33	2.08	38.89	34.69
	Total	2.93	1.94	44.44	35.45
Total	*Terminalia superba*	3.25	2.14	54.17	35.62
	Triplochiton scleroxylon	2.25	1.71	37.50	28.54
	Gmelina	5.17	0.94	84.72	13.22
	Khaya grandifoliola	1.67	1.78	27.78	29.59
	Cordia millenii	2.58	2.02	43.06	33.68
	Total	2.98	2.10	49.44	34.44

Appendix 9: Honey yield per colony (kg) based on wood samples

Wood species	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Terminalia superba	4.772[b]	.119	4.527	5.018
Triplochiton scleroxylon	5.209[b]	.114	4.974	5.444
Gmelina	5.911[c]	.097	5.710	6.111
Khaya grandifoliola	3.624[a]	.145	3.324	3.925
Cordia millenii	5.165[b]	.119	4.920	5.410

Appendix 10 Honey yield per colony (kg) based on Location

Location2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Adeaga	4.978	.099	4.773	5.182
Ayetoro	4.785	.113	4.551	5.019
Onifuufu	4.932	.113	4.699	5.166
Ogunmakin	5.050	.103	4.838	5.262

Appendix 11: Mean value of honey yield after harvesting

Location	Wood species	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Adeaga	*Terminalia superba*	5.441	.194	5.040	5.842
	Triplochiton scleroxylon	4.643	.237	4.152	5.134
	Gmelina	6.737	.194	6.337	7.138
	Khaya grandifoliola	3.563	.237	3.072	4.054
	Cordia millenii	4.504	.237	4.013	4.995
Ayetoro	*Terminalia superba*	5.044	.237	4.553	5.535
	Triplochiton scleroxylon	4.587	.237	4.096	5.078
	Gmelina	5.209	.194	4.809	5.610
	Khaya grandifoliola	3.439	.336	2.745	4.134
	Cordia millenii	5.645	.237	5.154	6.136
Onifuufu	*Terminalia superba*	5.252	.237	4.761	5.743
	Triplochiton scleroxylon	4.682	.237	4.191	5.173
	Gmelina	6.229	.194	5.829	6.630
	Khaya grandifoliola	3.440	.336	2.746	4.134
	Cordia millenii	5.058	.237	4.567	5.549
Ogunmakin	*Terminalia superba*	5.100	.237	4.609	5.591
	Triplochiton scleroxylon	5.177	.237	4.686	5.668
	Gmelina	5.466	.194	5.065	5.867
	Khaya grandifoliola	4.054	.237	3.563	4.545
	Cordia millenii	5.453	.237	4.962	5.944

a. This level combination of factors is not observed, thus the corresponding population marginal mean is not estimable.

Appendix 12: Pooled physical properties of the Wood Species in Oyo and Ogun States

	Volumetric shrinkage	Oven dry density (%)	Moisture Content (%)
Gmelina (Oyo)	5.69±1.35	450.49±15.64	14.83±0.37
Gmelina (Ogun)	6.24±1.39	449.18±15.49	15.17±0.36
Cordia milenni (Oyo)	6.07±1.27	395.61±58.50	15.74±0.52
Cordia milenni (Ogun)	6.56±1.22	397.29±58.48	15.24±0.53
Triplochiton scleroxylon (Oyo)	7.89±1.23	396.84±29.79	15.96±2.07
Triplochiton scleroxylon (Ogun)	8.78±1.06	393.70±29.88	16.57±0.60
Khaya grandifoliola (Oyo)	8.76±1.54	611.55±70.65	18.68±0.53
Khaya grandifoliola (Ogun)	8.80±1.14	608.34±70.85	18.62±2.13
Terminalia superba (Oyo)	6.27±1.52	376.51±33.11	15.05±0.55
Terminalia superba (Ogun)	6.26±1.49	368.54±32.23	17.57±0.11

Appendix 13: Pooled phytochemical properties of the wood species

	Alkaloids	Tannins	Saponins	Flavonoid	Cellulose	Cardiac	Phenol	Hemicellulose	Total lignin
Gmelina	392.24±2.05	130.59±2.58	71.17±2.20	174.65±6.8	101.09±3.39	77.34±1.29	38.04±0.18	115.835±3.88	18.165±2.45
Cordia Milleni	278.17±4.49	614.83±5.61	135.17±4.52	55.76±2.24	121.58±1.70	93.17±2.87	27.98±0.17	90.585±2.82	23.168±2.10
Triplochiton Scleroxylon	314.01±10.19	616.00±7.09	113.50±1.91	152.59±1.72	131.25±2.83	95.33±3.08	12.8±0.56	115.915±2.72	23.333±1.38
Khaya grandifoliola	217.16±11.66	773.08±11.15	167.67±8.62	45.34±1.99	111.09±3.56	89.25±2.44	28.93±0.24	130.998±2.49	25.415±1.93
Terminalia Superba	272.17±4.94	1300.67±10.16	129.75±4.44	166.26±16.48	107.33±3.59	80.92±2.07	63.00±0.55	134.248±3.17	24.000±1.65

Appendix 14: Wood for Hives construction and rate of Abscondment

Location	Wood species	Number Hives absconded	Percentage abscondment
Onifuufu	*Gmelina*	0	0
Onifuufu	*Cordia millenii*	1	33.3
Onifuufu	*Triplochiton scleroxylon*	1	33.3
Onifuufu	*Khaya grandifoliola*	2	66.6
Onifuufu	*Terminalia superba*	1	33.3
Ogunmakin	*Gmelina*	0	0
Ogunmakin	*Cordia millenii*	1	33.3
Ogunmakin	*Triplochiton scleroxylon*	1	33.3
Ogunmakin	*Khaya grandifoliola*	2	66.6
Ogunmakin	*Terminalia superba*	1	33.3
Adeaga	*Gmelina*	1	33.3
Adeaga	*Cordia millenii*	1	33.3
Adeaga	*Triplochiton scleroxylon*	1	33.3
Adeaga	*Khaya grandifoliola*	1	33.3
Adeaga	*Terminalia superba*	1	33.3
Ayetoro	*Gmelina*	0	0
Ayetoro	*Cordia millenii*	1	33.3
Ayetoro	*Triplochiton scleroxylon*	1	33.3
Ayetoro	*Khaya grandifoliola*	2	66.6
Ayetoro	*Terminalia superba*	1	33.3

s

Appendix 15: SPSS output for data analysed in the study

Oneway

ANOVA

Honeyyield

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.466	3	.822	2.732	.048
Within Groups	28.893	96	.301		
Total	31.359	99			

Oneway

Descriptives

VAR00001

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Terminalia superba	9	5.2351	.17639	.05880	5.0995	5.3707	5.01	5.52
Triplochiton scleroxylon	8	4.7721	.25512	.09020	4.5589	4.9854	4.56	5.23
Gmelina	12	5.9105	.73556	.21234	5.4432	6.3779	5.17	6.74
Khaya grandifoliola	6	5.1857	.56512	.23071	4.5926	5.7787	4.45	5.66
Cordia milenni	6	5.0690	.56693	.23145	4.4741	5.6640	4.48	5.72
Total	41	5.3109	.65180	.10179	5.1052	5.5167	4.45	6.74

ANOVA

VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7.134	4	1.783	6.512	.000
Within Groups	9.860	36	.274		
Total	16.994	40			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: VAR00001
Scheffe

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.46297	.25430	.516	-.3624	1.2883
	Gmelina	-.67544	.23077	.096	-1.4244	.0736
	Khaya grandifoliola	.04941	.27583	1.000	-.8458	.9446
	Cordia millenii	.16608	.27583	.985	-.7292	1.0613
Triplochiton scleroxylon	*Terminalia superba*	-.46297	.25430	.516	-1.2883	.3624
	Triplochiton scleroxylon					
	Gmelina	-1.13841*	.23887	.001	-1.9137	-.3631
	Khaya grandifoliola	-.41355	.28264	.711	-1.3309	.5038
	Cordia millenii	-.29689	.28264	.892	-1.2142	.6205
Gmelina	*Terminalia superba*	.67544	.23077	.096	-.0736	1.4244
	Triplochiton scleroxylon	1.13841*	.23887	.001	.3631	1.9137
	Gmelina					
	Khaya grandifoliola	.72485	.26167	.129	-.1244	1.5741
	Cordia milleniii	.84152	.26167	.053	-.0078	1.6908
Khaya grandifoliola	*Terminalia superba*	-.04941	.27583	1.000	-.9446	.8458
	Triplochiton scleroxylon	.41355	.28264	.711	-.5038	1.3309
	Gmelina	-.72485	.26167	.129	-1.5741	.1244
	Khaya grandifoliola					
	Cordia milleniii	.11667	.30215	.997	-.8640	1.0973
Cordia millenii	*Terminalia superba*	-.16608	.27583	.985	-1.0613	.7292
	Triplochiton scleroxylon	.29689	.28264	.892	-.6205	1.2142
	Gmelina	-.84152	.26167	.053	-1.6908	.0078
	Khaya grandifoliola	-.11667	.30215	.997	-1.0973	.8640
	Cordia millenii					

*. The mean difference is significant at the 0.05 level.

HCordia milennigeneous Subsets

VAR00001

Scheffe			
Woodspecies 2	N	Subset for alpha = 0.05	
		1	2
Triplochiton scleroxylon	8	4.7721	
Cordia millenii	6	5.0690	5.0690
Khaya grandifoliola	6	5.1857	5.1857
Terminalia superba	9	5.2351	5.2351
Gmelina	12		5.9105
Sig.		.565	.062

Means for groups in hCordia milennigeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 7.660.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Location2	1	Adeaga	12
	2	Ayetoro	10
	3	Onifuufu	10
	4	Ogunmakin	9
Woodspecies 2	1	*Terminalia superba*	9
	2	*Triplochiton scleroxylon*	8
	3	*Gmelina*	12
	4	*Khaya grandifoliola*	6
	5	*Cordia millenii*	6

Descriptive Statistics

Dependent Variable: VAR00001				
Location2	Woodspecies2	Mean	Std. Deviation	N
Adeaga	*Terminalia superba*	5.4412	.06419	3
	Triplochiton scleroxylon	4.6429	.04575	2
	Gmelina	6.7375	.00272	3
	Khaya grandifoliola	5.0629	.82440	2
	Cordia milenni	4.5038	.03369	2
	Total	5.4129	.90656	12
Ayetoro	*Terminalia superba*	5.0444	.04867	2
	Triplochiton scleroxylon	4.5868	.03369	2
	Gmelina	5.2094	.06215	3
	Khaya grandifoliola	5.4394	.	1
	Cordia milenni	5.6450	.10856	2
	Total	5.1620	.37457	10
Onifuufu	*Terminalia superba*	5.2518	.01664	2
	Triplochiton scleroxylon	4.6821	.01622	2
	Gmelina	6.2294	.85686	3
	Khaya grandifoliola	5.4400	.	1
	Cordia milenni	5.0582	.53990	2
	Total	5.4112	.75520	10
Ogunmakin	*Terminalia superba*	5.1000	.02912	2
	Triplochiton scleroxylon	5.1768	.07945	2
	Gmelina	5.4659	.15996	3
	Khaya grandifoliola Cordia milenni	5.0544	.85061	2
	Total	5.2289	.36227	9
Total	*Terminalia superba*	5.2351	.17639	9
	Triplochiton scleroxylon	4.7721	.25512	8
	Gmelina	5.9105	.73556	12
	Khaya grandifoliola	5.1857	.56512	6
	Cordia millenii	5.0690	.56693	6
	Total	5.3109	.65180	41

Tests of Between-Subjects Effects

Dependent Variable: VAR00001

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	13.737[a]	18	.763	5.156	.000	.808
Intercept	1021.496	1	1021.496	6901.073	.000	.997
Location2	.184	3	.061	.414	.745	.053
Woodspecies2	7.165	4	1.791	12.101	.000	.688
Location2 * Woodspecies2	5.975	11	.543	3.670	.005	.647
Error	3.256	22	.148			
Total	1173.434	41				
Corrected Total	16.994	40				

a. R Squared = .808 (Adjusted R Squared = .652)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: VAR00001

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
5.251[a]	.063	5.121	5.382

a. Based on modified population marginal mean.

2. Location2

Estimates

Dependent Variable: VAR00001

Location2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Adeaga	5.278	.113	5.043	5.513
Ayetoro	5.185	.130	4.916	5.454
Onifuufu	5.332	.130	5.064	5.601
Ogunmakin	5.199[a]	.130	4.929	5.469

a. Based on modified population marginal mean.

Pairwise Comparisons

Dependent Variable: VAR00001						
(I) Location2	(J) Location2	Mean Difference (I-J)	Std. Error	Sig.[c]	95% Confidence Interval for Difference[c]	
					Lower Bound	Upper Bound
Adeaga	*Adeaga*					
	Ayetoro	.093	.172	.596	-.264	.449
	Onifuufu	-.055	.172	.754	-.411	.302
	Ogunmakin	.078[a]	.173	.654	-.280	.436
Ayetoro	*Adeaga*	-.093	.172	.596	-.449	.264
	Ayetoro					
	Onifuufu	-.147	.183	.430	-.527	.233
	Ogunmakin	-.014[a]	.184	.939	-.395	.367
Onifuufu	*Adeaga*	.055	.172	.754	-.302	.411
	Ayetoro	.147	.183	.430	-.233	.527
	Onifuufu					
	Ogunmakin	.133[a]	.184	.477	-.248	.514
Ogunmakin	*Adeaga*	-.078[b]	.173	.654	-.436	.280
	Ayetoro	.014[b]	.184	.939	-.367	.395
	Onifuufu	-.133[b]	.184	.477	-.514	.248
	Ogunmakin					

Based on estimated marginal means

a. An estimate of the modified population marginal mean (J).

b. An estimate of the modified population marginal mean (I).

c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Test

Dependent Variable: VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	.128	3	.043	.289	.833	.038
Error	3.256	22	.148			

The F tests the effect of Location2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Woodspecies2

Estimates

Dependent Variable: VAR00001

Woodspecies 2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Terminalia superba	5.209	.130	4.939	5.479
Triplochiton scleroxylon	4.772	.136	4.490	5.054
Gmelina	5.911	.111	5.680	6.141
Khaya grandifoliola	5.249	.167	4.904	5.595
Cordia millenii	5.069[a]	.157	4.743	5.395

a. Based on modified population marginal mean.

Pairwise Comparisons

Dependent Variable: VAR00001

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.[d]	95% Confidence Interval for Difference[d]	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.437*	.188	.030	.047	.828
	Gmelina	-.701*	.171	.000	-1.056	-.346
	Khaya grandifoliola	-.040	.211	.852	-.478	.399
	Cordia millenii	.140[b]	.204	.499	-.283	.563
Triplochiton scleroxylon	*Terminalia superba*	-.437*	.188	.030	-.828	-.047
	Triplochiton scleroxylon					
	Gmelina	-1.138*	.176	.000	-1.503	-.774
	Khaya grandifoliola	-.477*	.215	.037	-.923	-.031
	Cordia millenii	-.297[b]	.208	.167	-.728	.134
Gmelina	*Terminalia superba*	.701*	.171	.000	.346	1.056
	Triplochiton scleroxylon	1.138*	.176	.000	.774	1.503
	Gmelina					
	Khaya grandifoliola	.661*	.200	.003	.246	1.077
	Cordia millenii	.842*,[b]	.192	.000	.443	1.240
Khaya grandifoliola	*Terminalia superba*	.040	.211	.852	-.399	.478
	Triplochiton scleroxylon	.477*	.215	.037	.031	.923
	Gmelina	-.661*	.200	.003	-1.077	-.246
	Khaya grandifoliola					
	Cordia millenii	.180[b]	.229	.440	-.295	.655
Cordia millenii	*Terminalia superba*	-.140[c]	.204	.499	-.563	.283
	Triplochiton scleroxylon	.297[c]	.208	.167	-.134	.728
	Gmelina	-.842*,[c]	.192	.000	-1.240	-.443
	Khaya grandifoliola	-.180[c]	.229	.440	-.655	.295
	Cordia millenii					

Based on estimated marginal means

*. The mean difference is significant at the .05 level.
b. An estimate of the modified population marginal mean (J).
c. An estimate of the modified population marginal mean (I).
d. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	7.097	4	1.774	11.987	.000	.685
Error	3.256	22	.148			

The F tests the effect of Woodspecies2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Location2 * Woodspecies2

Dependent Variable: VAR00001

Location2	Woodspecies2	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Adeaga	*Terminalia superba*	5.441	.222	4.981	5.902
	Triplochiton scleroxylon	4.643	.272	4.079	5.207
	Gmelina	6.737	.222	6.277	7.198
	Khaya grandifoliola	5.063	.272	4.499	5.627
	Cordia millenii	4.504	.272	3.940	5.068
Ayetoro	*Terminalia superba*	5.044	.272	4.480	5.609
	Triplochiton scleroxylon	4.587	.272	4.023	5.151
	Gmelina	5.209	.222	4.749	5.670
	Khaya grandifoliola	5.439	.385	4.642	6.237
	Cordia millenii	5.645	.272	5.081	6.209
Onifuufu	*Terminalia superba*	5.252	.272	4.688	5.816
	Triplochiton scleroxylon	4.682	.272	4.118	5.246
	Gmelina	6.229	.222	5.769	6.690
	Khaya grandifoliola	5.440	.385	4.642	6.238
	Cordia millenii	5.058	.272	4.494	5.622
Ogunmakin	*Terminalia superba*	5.100	.272	4.536	5.664
	Triplochiton scleroxylon	5.177	.272	4.613	5.741
	Gmelina	5.466	.222	5.005	5.927
	Khaya grandifoliola	5.054	.272	4.490	5.619
	Cordia millenii	.[a]	.	.	.

a. This level combination of factors is not observed, thus the corresponding population marginal mean is not estimable.

Post Hoc Tests
Location2

Multiple Comparisons

Dependent Variable: VAR00001
Scheffe

(I) Location2	(J) Location2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Adeaga	Adeaga					
	Ayetoro	.2509	.16473	.521	-.2473	.7492
	Onifuufu	.0017	.16473	1.000	-.4965	.4999
	Ogunmakin	.1841	.16965	.760	-.3291	.6972
Ayetoro	Adeaga	-.2509	.16473	.521	-.7492	.2473
	Ayetoro					
	Onifuufu	-.2492	.17206	.562	-.7696	.2711
	Ogunmakin	-.0669	.17677	.986	-.6015	.4678
Onifuufu	Adeaga	-.0017	.16473	1.000	-.4999	.4965
	Ayetoro	.2492	.17206	.562	-.2711	.7696
	Onifuufu					
	Ogunmakin	.1823	.17677	.786	-.3523	.7170
Ogunmakin	Adeaga	-.1841	.16965	.760	-.6972	.3291
	Ayetoro	.0669	.17677	.986	-.4678	.6015
	Onifuufu	-.1823	.17677	.786	-.7170	.3523
	Ogunmakin					

Based on observed means.
The error term is Mean Square(Error) = .148.

HCordia milennigeneous Subsets

VAR00001

Scheffe

Location2	N	Subset 1
Ayetoro	10	5.1620
Ogunmakin	9	5.2289
Onifuufu	10	5.4112
Adeaga	12	5.4129
Sig.		.551

Means for groups in hCordia milennigeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .148.

a. Uses Harmonic Mean Sample Size = 10.141.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Woodspecies2

Multiple Comparisons

Dependent Variable: VAR00001

Scheffe

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.4630	.18695	.227	-.1645	1.0905
	Gmelina	-.6754*	.16965	.014	-1.2449	-.1060
	Khaya grandifoliola	.0494	.20277	1.000	-.6312	.7300
	Cordia millenii	.1661	.20277	.953	-.5145	.8467
Triplochiton scleroxylon	*Terminalia superba*	-.4630	.18695	.227	-1.0905	.1645
	Triplochiton scleroxylon					
	Gmelina	-1.1384*	.17561	.000	-1.7278	-.5490
	Khaya grandifoliola	-.4136	.20778	.433	-1.1110	.2839
	Cordia millenii	-.2969	.20778	.729	-.9943	.4005
Gmelina	*Terminalia superba*	.6754*	.16965	.014	.1060	1.2449
	Triplochiton scleroxylon	1.1384*	.17561	.000	.5490	1.7278
	Gmelina					
	Khaya grandifoliola	.7249*	.19237	.022	.0792	1.3706
	Cordia millenii	.8415*	.19237	.006	.1958	1.4872
Khaya grandifoliola	*Terminalia superba*	-.0494	.20277	1.000	-.7300	.6312
	Triplochiton scleroxylon	.4136	.20778	.433	-.2839	1.1110
	Gmelina	-.7249*	.19237	.022	-1.3706	-.0792
	Khaya grandifoliola					
	Cordia millenii	.1167	.22213	.991	-.6289	.8623

Cordia millenii	*Terminalia superba*	-.1661	.20277	.953	-.8467	.5145
	Triplochiton scleroxylon	.2969	.20778	.729	-.4005	.9943
	Gmelina	-.8415*	.19237	.006	-1.4872	-.1958
	Khaya grandifoliola	-.1167	.22213	.991	-.8623	.6289
	Cordia millenii					

Based on observed means.

The error term is Mean Square(Error) = .148.

*. The mean difference is significant at the .05 level.

HCordia milennigeneous Subsets

VAR00001

Scheffe Woodspecies	N	Subset 1	2
Triplochiton scleroxylon	8	4.7721	
Cordia millenii	6	5.0690	
Khaya grandifoliola	6	5.1857	
Terminalia superba	9	5.2351	
Gmelina	12		5.9105
Sig.		.271	1.000

Means for groups in hCordia milennigeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .148.

a. Uses Harmonic Mean Sample Size = 7.660.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Oneway

Descriptives

VAR00001

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Terminalia superba	9	5.2351	.17639	.05880	5.0995	5.3707	5.01	5.52
Triplochiton scleroxylon	8	4.7721	.25512	.09020	4.5589	4.9854	4.56	5.23
Gmelina	12	5.9105	.73556	.21234	5.4432	6.3779	5.17	6.74
Khaya grandifoliola	6	5.1857	.56512	.23071	4.5926	5.7787	4.45	5.66
Cordia millenii	8	4.9150	.55759	.19714	4.4488	5.3812	4.45	5.72
Total	43	5.2710	.66184	.10093	5.0673	5.4747	4.45	6.74

ANOVA

VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7.968	4	1.992	7.258	.000
Within Groups	10.429	38	.274		
Total	18.398	42			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: VAR00001

Scheffe

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.46297	.25456	.516	-.3610	1.2869
	Gmelina	-.67544	.23101	.095	-1.4231	.0723
	Khaya grandifoliola	.04941	.27611	1.000	-.8443	.9431
	Cordia millenii	.32010	.25456	.811	-.5038	1.1440
Triplochiton scleroxylon	*Terminalia superba*	-.46297	.25456	.516	-1.2869	.3610
	Triplochiton scleroxylon					
	Gmelina	-1.13841*	.23912	.001	-1.9124	-.3645
	Khaya grandifoliola	-.41355	.28293	.711	-1.3293	.5022
	Cordia millenii	-.14287	.26194	.990	-.9907	.7050
Gmelina	*Terminalia superba*	.67544	.23101	.095	-.0723	1.4231
	Triplochiton scleroxylon	1.13841*	.23912	.001	.3645	1.9124
	Gmelina					
	Khaya grandifoliola	.72485	.26194	.128	-.1230	1.5727
	Cordia millenii	.99554*	.23912	.006	.2216	1.7695
Khaya grandifoliola	*Terminalia superba*	-.04941	.27611	1.000	-.9431	.8443
	Triplochiton scleroxylon	.41355	.28293	.711	-.5022	1.3293
	Gmelina	-.72485	.26194	.128	-1.5727	.1230
	Khaya grandifoliola					

	Cordia millenii	.27069	.28293	.921	-.6451	1.1864
Cordia millenii	*Terminalia superba*	-.32010	.25456	.811	-1.1440	.5038
	Triplochiton scleroxylon	.14287	.26194	.990	-.7050	.9907
	Gmelina	-.99554*	.23912	.006	-1.7695	-.2216
	Khaya grandifoliola	-.27069	.28293	.921	-1.1864	.6451
	Cordia millenii					

*. The mean difference is significant at the 0.05 level.

HCordia milennigeneous Subsets
VAR00001

Scheffe Woodspecies 2	N	Subset for alpha = 0.05	
		1	2
Triplochiton scleroxylon	8	4.7721	
Cordia millenii	8	4.9150	
Khaya grandifoliola	6	5.1857	5.1857
Terminalia superba	9	5.2351	5.2351
Gmelina	12		5.9105
Sig.		.534	.121

Means for groups in hCordia milennigeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.182.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Oneway

Descriptives

VAR00001

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Terminalia superba	9	5.2351	.17639	.05880	5.0995	5.3707	5.01	5.52
Triplochiton scleroxylon	8	4.7721	.25512	.09020	4.5589	4.9854	4.56	5.23
Gmelina	12	5.9105	.73556	.21234	5.4432	6.3779	5.17	6.74
Khaya grandifoliola	6	5.1857	.56512	.23071	4.5926	5.7787	4.45	5.66
Cordia millenii	8	5.1650	.51104	.18068	4.7378	5.5922	4.48	5.72
Total	43	5.3175	.63681	.09711	5.1215	5.5135	4.45	6.74

ANOVA

VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6.951	4	1.738	6.550	.000
Within Groups	10.081	38	.265		
Total	17.032	42			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: VAR00001

Scheffe

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.46297	.25028	.499	-.3471	1.2730
	Gmelina	-.67544	.22712	.086	-1.4106	.0597
	Khaya grandifoliola	.04941	.27146	1.000	-.8292	.9280
	Cordia millenii	.07010	.25028	.999	-.7400	.8802
Triplochiton scleroxylon	*Terminalia superba*	-.46297	.25028	.499	-1.2730	.3471
	Triplochiton scleroxylon					
	Gmelina	-1.13841*	.23509	.001	-1.8993	-.3775
	Khaya grandifoliola	-.41355	.27817	.698	-1.3139	.4868
	Cordia millenii	-.39287	.25753	.678	-1.2264	.4407
Gmelina	*Terminalia superba*	.67544	.22712	.086	-.0597	1.4106
	Triplochiton scleroxylon	1.13841*	.23509	.001	.3775	1.8993
	Gmelina					
	Khaya grandifoliola	.72485	.25753	.117	-.1087	1.5584

	Cordia millenii	.74554	.23509	.057	-.0154	1.5065
Khaya grandifoliola	*Terminalia superba*	-.04941	.27146	1.000	-.9280	.8292
	Triplochiton scleroxylon	.41355	.27817	.698	-.4868	1.3139
	Gmelina	-.72485	.25753	.117	-1.5584	.1087
	Khaya grandifoliola					
	Cordia millenii	.02069	.27817	1.000	-.8796	.9210
Cordia millenii	*Terminalia superba*	-.07010	.25028	.999	-.8802	.7400
	Triplochiton scleroxylon	.39287	.25753	.678	-.4407	1.2264
	Gmelina	-.74554	.23509	.057	-1.5065	.0154
	Khaya grandifoliola	-.02069	.27817	1.000	-.9210	.8796
	Cordia millenii					

*. The mean difference is significant at the 0.05 level.

HCordia milennigeneous Subsets

VAR00001

Scheffe Woodspecies 2	N	Subset for alpha = 0.05	
		1	2
Triplochiton scleroxylon	8	4.7721	
Cordia millenii	8	5.1650	5.1650
Khaya grandifoliola	6	5.1857	5.1857
Terminalia superba	9	5.2351	5.2351
Gmelina	12		5.9105
Sig.		.517	.094

Means for groups in hCordia milennigeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 8.182.
b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Univariate Analysis of Variance

Between-Subjects Factors

	Value Label		N
Location2	1	Adeaga	12
	2	Ayetoro	10
	3	Onifuufu	10
	4	Ogunmakin	11
Woodspecies 2	1	*Terminalia superba*	9
	2	*Triplochiton scleroxylon*	8
	3	*Gmelina*	12
	4	*Khaya grandifoliola*	6
	5	*Cordia millenii*	8

Descriptive Statistics

Dependent Variable: VAR00001

Location2	Woodspecies2	Mean	Std. Deviation	N
Adeaga	*Terminalia superba*	5.4412	.06419	3
	Triplochiton scleroxylon	4.6429	.04575	2
	Gmelina	6.7375	.00272	3
	Khaya grandifoliola	3.5629	.11730	2
	Cordia millenii	4.5038	.03369	2
	Total	5.1629	1.13716	12
Ayetoro	*Terminalia superba*	5.0444	.04867	2
	Triplochiton scleroxylon	4.5868	.03369	2
	Gmelina	5.2094	.06215	3
	Khaya grandifoliola	3.4394	.	1
	Cordia millenii	5.6450	.10856	2
	Total	4.9620	.64576	10
Onifuufu	*Terminalia superba*	5.2518	.01664	2
	Triplochiton scleroxylon	4.6821	.01622	2
	Gmelina	6.2294	.85686	3
	Khaya grandifoliola	3.4400	.	1
	Cordia millenii	5.0582	.53990	2
	Total	5.2112	.97854	10
Ogunmakin	*Terminalia superba*	5.1000	.02912	2
	Triplochiton scleroxylon	5.1768	.07945	2
	Gmelina	5.4659	.15996	3
	Khaya grandifoliola	4.0544	.85061	2
	Cordia millenii	5.4529	.00000	2
	Total	5.0878	.60243	11
Total	*Terminalia superba*	5.2351	.17639	9
	Triplochiton scleroxylon	4.7721	.25512	8
	Gmelina	5.9105	.73556	12
	Khaya grandifoliola	3.6857	.48174	6
	Cordia millenii	5.1650	.51104	8
	Total	5.1082	.85336	43

Tests of Between-Subjects Effects

Dependent Variable: VAR00001

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	27.995[a]	19	1.473	13.081	.000	.915
Intercept	958.681	1	958.681	8511.554	.000	.997
Location2	.358	3	.119	1.059	.386	.121
Woodspecies2	20.486	4	5.121	45.471	.000	.888
Location2 * Woodspecies2	6.419	12	.535	4.749	.001	.712
Error	2.591	23	.113			
Total	1152.624	43				
Corrected Total	30.585	42				

a. R Squared = .915 (Adjusted R Squared = .845)

Estimated Marginal Means

1. Grand Mean

Dependent Variable: VAR00001

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
4.936	.054	4.826	5.047

2. Location2

Estimates

Dependent Variable: VAR00001

Location2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Adeaga	4.978	.099	4.773	5.182
Ayetoro	4.785	.113	4.551	5.019
Onifuufu	4.932	.113	4.699	5.166
Ogunmakin	5.050	.103	4.838	5.262

Pairwise Comparisons

Dependent Variable: VAR00001

(I) Location2	(J) Location2	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
Adeaga	Adeaga					
	Ayetoro	.193	.150	.212	-.118	.503
	Onifuufu	.045	.150	.765	-.265	.356
	Ogunmakin	-.072	.142	.616	-.367	.222
Ayetoro	Adeaga	-.193	.150	.212	-.503	.118
	Ayetoro					
	Onifuufu	-.147	.160	.366	-.478	.183
	Ogunmakin	-.265	.153	.096	-.581	.051
Onifuufu	Adeaga	-.045	.150	.765	-.356	.265
	Ayetoro	.147	.160	.366	-.183	.478
	Onifuufu					
	Ogunmakin	-.118	.153	.448	-.433	.198
Ogunmakin	Adeaga	.072	.142	.616	-.222	.367
	Ayetoro	.265	.153	.096	-.051	.581
	Onifuufu	.118	.153	.448	-.198	.433
	Ogunmakin					

Based on estimated marginal means

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	.358	3	.119	1.059	.386	.121
Error	2.591	23	.113			

The F tests the effect of Location2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

3. Woodspecies2

Estimates

Dependent Variable: VAR00001

Woodspecies2	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Terminalia superba	5.209	.114	4.974	5.444
Triplochiton scleroxylon	4.772	.119	4.527	5.018
Gmelina	5.911	.097	5.710	6.111
Khaya grandifoliola	3.624	.145	3.324	3.925
Cordia millenii	5.165	.119	4.920	5.410

Pairwise Comparisons

Dependent Variable: VAR00001

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.437*	.164	.014	.097	.777
	Gmelina	-.701*	.149	.000	-1.010	-.392
	Khaya grandifoliola	1.585*	.184	.000	1.204	1.967
	Cordia millenii	.044	.164	.790	-.295	.384
Triplochiton scleroxylon	*Terminalia superba*	-.437*	.164	.014	-.777	-.097
	Triplochiton scleroxylon					
	Gmelina	-1.138*	.153	.000	-1.455	-.822
	Khaya grandifoliola	1.148*	.188	.000	.760	1.536
	Cordia millenii	-.393*	.168	.028	-.740	-.046
Gmelina	*Terminalia superba*	.701*	.149	.000	.392	1.010
	Triplochiton scleroxylon	1.138*	.153	.000	.822	1.455
	Gmelina					
	Khaya grandifoliola	2.286*	.175	.000	1.925	2.648
	Cordia millenii	.746*	.153	.000	.429	1.062
Khaya grandifoliola	*Terminalia superba*	-1.585*	.184	.000	-1.967	-1.204
	Triplochiton scleroxylon	-1.148*	.188	.000	-1.536	-.760
	Gmelina	-2.286*	.175	.000	-2.648	-1.925
	Khaya grandifoliola					
	Cordia millenii	-1.541*	.188	.000	-1.929	-1.153
Cordia millenii	*Terminalia superba*	-.044	.164	.790	-.384	.295
	Triplochiton scleroxylon	.393*	.168	.028	.046	.740
	Gmelina	-.746*	.153	.000	-1.062	-.429
	Khaya grandifoliola	1.541*	.188	.000	1.153	1.929
	Cordia millenii					

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Univariate Tests

Dependent Variable: VAR00001

	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	20.486	4	5.121	45.471	.000	.888
Error	2.591	23	.113			

The F tests the effect of Woodspecies2. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

4. Location2 * Woodspecies2

Dependent Variable: VAR00001

Location2	Woodspecies2	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Adeaga	*Terminalia superba*	5.441	.194	5.040	5.842
	Triplochiton scleroxylon	4.643	.237	4.152	5.134
	Gmelina	6.737	.194	6.337	7.138
	Khaya grandifoliola	3.563	.237	3.072	4.054
	Cordia millenii	4.504	.237	4.013	4.995
Ayetoro	*Terminalia superba*	5.044	.237	4.553	5.535
	Triplochiton scleroxylon	4.587	.237	4.096	5.078
	Gmelina	5.209	.194	4.809	5.610
	Khaya grandifoliola	3.439	.336	2.745	4.134
	Cordia millenii	5.645	.237	5.154	6.136
Onifuufu	*Terminalia superba*	5.252	.237	4.761	5.743
	Triplochiton scleroxylon	4.682	.237	4.191	5.173
	Gmelina	6.229	.194	5.829	6.630
	Khaya grandifoliola	3.440	.336	2.746	4.134
	Cordia millenii	5.058	.237	4.567	5.549
Ogunmakin	*Terminalia superba*	5.100	.237	4.609	5.591
	Triplochiton scleroxylon	5.177	.237	4.686	5.668
	Gmelina	5.466	.194	5.065	5.867
	Khaya grandifoliola	4.054	.237	3.563	4.545
	Cordia millenii	5.453	.237	4.962	5.944

Post Hoc Tests
Location2

Multiple Comparisons

Dependent Variable: VAR00001
Scheffe

(I) Location2	(J) Location2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Adeaga	Adeaga					
	Ayetoro	.2009	.14370	.590	-.2322	.6340
	Onifuufu	-.0483	.14370	.990	-.4814	.3848
	Ogunmakin	.0751	.14009	.962	-.3471	.4974
Ayetoro	Adeaga	-.2009	.14370	.590	-.6340	.2322
	Ayetoro					
	Onifuufu	-.2492	.15009	.447	-.7016	.2031
	Ogunmakin	-.1258	.14664	.864	-.5678	.3162
Onifuufu	Adeaga	.0483	.14370	.990	-.3848	.4814
	Ayetoro	.2492	.15009	.447	-.2031	.7016
	Onifuufu					
	Ogunmakin	.1234	.14664	.870	-.3185	.5654
Ogunmakin	Adeaga	-.0751	.14009	.962	-.4974	.3471
	Ayetoro	.1258	.14664	.864	-.3162	.5678
	Onifuufu	-.1234	.14664	.870	-.5654	.3185
	Ogunmakin					

Based on observed means.
The error term is Mean Square(Error) = .113.

HCordia milennigeneous Subsets

VAR00001

Scheffe

Location2	N	Subset 1
Ayetoro	10	4.9620
Ogunmakin	11	5.0878
Adeaga	12	5.1629
Onifuufu	10	5.2112
Sig.		.418

Means for groups in hCordia milennigeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .113.

a. Uses Harmonic Mean Sample Size = 10.688.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Woodspecies2

Multiple Comparisons

Dependent Variable: VAR00001

Scheffe

(I) Woodspecies2	(J) Woodspecies2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Terminalia superba	*Terminalia superba*					
	Triplochiton scleroxylon	.4630	.16308	.126	-.0824	1.0083
	Gmelina	-.6754*	.14799	.004	-1.1703	-.1806
	Khaya grandifoliola	1.5494*	.17688	.000	.9579	2.1409
	Cordia millenii	.0701	.16308	.996	-.4752	.6154
Triplochiton scleroxylon	*Terminalia superba*	-.4630	.16308	.126	-1.0083	.0824
	Triplochiton scleroxylon					
	Gmelina	-1.1384*	.15318	.000	-1.6506	-.6262
	Khaya grandifoliola	1.0864*	.18125	.000	.4804	1.6925
	Cordia millenii	-.3929	.16780	.275	-.9540	.1683
Gmelina	*Terminalia superba*	.6754*	.14799	.004	.1806	1.1703
	Triplochiton scleroxylon	1.1384*	.15318	.000	.6262	1.6506
	Gmelina					
	Khaya grandifoliola	2.2249*	.16780	.000	1.6637	2.7860
	Cordia millenii	.7455*	.15318	.002	.2333	1.2578
Khaya grandifoliola	*Terminalia superba*	-1.5494*	.17688	.000	-2.1409	-.9579
	Triplochiton scleroxylon	-1.0864*	.18125	.000	-1.6925	-.4804
	Gmelina	-2.2249*	.16780	.000	-2.7860	-1.6637
	Khaya grandifoliola					
	Cordia millenii	-1.4793*	.18125	.000	-2.0854	-.8732
Cordia millenii	*Terminalia superba*	-.0701	.16308	.996	-.6154	.4752
	Triplochiton scleroxylon	.3929	.16780	.275	-.1683	.9540
	Gmelina	-.7455*	.15318	.002	-1.2578	-.2333

	Khaya grandifoliola *Cordia millenii*	1.4793*	.18125	.000	.8732	2.0854

Based on observed means.
The error term is Mean Square(Error) = .113.
*. The mean difference is significant at the .05 level.

HCordia milennigeneous Subsets

VAR00001

Scheffe Woodspecies	N	Subset 1	2	3
Khaya grandifoliola	6	3.6857		
Triplochiton scleroxylon	8		4.7721	
Cordia millenii	8		5.1650	
Terminalia superba	9		5.2351	
Gmelina	12			5.9105
Sig.		1.000	.137	1.000

Means for groups in hCordia milennigeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .113.

a. Uses Harmonic Mean Sample Size = 8.182.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

Regression

Wood species = Gmelina

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.930[b]	.864	.814	4.79923

a. Wood species = Gmelina

b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1174.946	3	391.649	17.004	.001[c]
	Residual	184.261	8	23.033		
	Total	1359.207	11			

a. Wood species = Gmelina

b. Dependent Variable: Colonisation

c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	37.743	3.491		10.810	.000			
	Flavonoid	.028	.027	.288	7.038	.001			
	Phenolic	.013	.001	.428	9.085	.004			
	Alkaloids	.062	.004	.691	12.690	.000			

a. Wood species = Gmelina

b. Dependent Variable: Colonisation

Wood species = *Cordia millenii*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.906[b]	.821	.754	1.23285

a. Wood species = Cordia millenii
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	55.746	3	18.582	12.226	.002[c]
	Residual	12.159	8	1.520		
	Total	67.906	11			

a. Wood species = Cordia millenii
b. Dependent Variable: Colonisation
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	45.708	2.895		15.791	.000			
	Flavonoid	-.003	.017	-.094	-.190	.854			
	Phenolic	-.122	.070	-1.000	-1.737	.121			
	Alkaloids	-.013	.007	-.406	-1.750	.118			

a. Wood species = Cordia millenii
b. Dependent Variable: Colonisation

Wood species = *Triplochiton scleroxylon*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.809[b]	.654	.525	10.99456

a. Wood species = Triplochiton scleroxylon
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1831.086	3	610.362	5.049	.030[c]
	Residual	967.043	8	120.880		
	Total	2798.129	11			

a. Wood species = Triplochiton scleroxylon
b. Dependent Variable: Colonisation
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	280.270	93.744		2.990	.017			
	Flavonoid	-.246	.124	-1.562	-1.983	.083			
	Phenolic	-4.597	1.716	-2.909	-2.680	.028			
	Alkaloids	-.360	.169	-1.753	-2.134	.065			

a. Wood species = Triplochiton scleroxylon
b. Dependent Variable: Colonisation

Wood species = Khaya grandifoliola

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.999[b]	.998	.997	.57735

a. Wood species = Khaya grandifoliola
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1459.215	3	486.405	1459.215	.000[c]
	Residual	2.667	8	.333		
	Total	1461.882	11			

a. Wood species = Khaya grandifoliola
b. Dependent Variable: Colonisation
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	66.196	1.578		41.958	.000			
	Flavonoid	.108	.003	.853	36.604	.000			
	Phenolic	-.206	.015	-.470	-13.275	.000			
	Alkaloids	-.155	.003	-1.241	-44.599	.000			

a. Wood species = Khaya grandifoliola
b. Dependent Variable: Colonisation

Wood species = Terminalia superba

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.970[b]	.940	.918	1.60806

a. Wood species = Terminalia superba
b. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	324.595	3	108.198	41.843	.000[c]
	Residual	20.687	8	2.586		
	Total	345.282	11			

a. Wood species = Terminalia superba
b. Dependent Variable: Colonisation
c. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	30.771	2.353		13.076	.000			
	Flavonoid	.051	.007	-.632	7.600	.000			
	Phenolic	-.091	.022	-.421	4.075	.004			
	Alkaloids	-.002	.009	-.034	-.222	.830			

a. Wood species = Terminalia superba
b. Dependent Variable: Colonisation

Wood species = Gmelina

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.837[b]	.701	.589	13.22699

a. Wood species = Gmelina
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3277.164	3	1092.388	6.644	.007[c]
	Residual	1399.625	8	164.953		
	Total	4676.790	11			

a. Wood species = Gmelina
b. Dependent Variable: Abscondment
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	49.159	10.127		4.854	.001			
	Flavonoid	-.050	.008	-.427	-6.256	.017			
	Phenolic	-.400	.052	-.559	-8.004	.002			
	Alkaloids	-.019	.003	-.330	-6.383	.000			

a. Wood species = Gmelina
b. Dependent Variable: Abscondment

Wood species = *Cordia millenii*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.897[b]	.805	.732	9.99047

a. Wood species = Cordia millenii
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	3301.313	3	1100.438	11.025	.003[c]
	Residual	798.476	8	99.809		
	Total	4099.789	11			

a. Wood species = Cordia millenii
b. Dependent Variable: Abscondment
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	60.068	23.457		2.561	.034			
	Flavonoid	-.112	.135	-.429	-.829	.431			
	Phenolic	.749	.571	.787	1.311	.226			
	Alkaloids	-.134	.060	-.541	-2.236	.056			

a. Wood species = Cordia millenii
b. Dependent Variable: Abscondment

Wood species =*Triplochiton scleroxylon*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[b]	1.000	.999	.62337

a. Wood species = Triplochiton scleroxylon
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	6666.267	3	2222.089	5718.314	.000[c]
	Residual	3.109	8	.389		
	Total	6669.376	11			

a. Wood species = Triplochiton scleroxylon
b. Dependent Variable: Abscondment
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	-384.230	5.315		-72.290	.000			
	Flavonoid	.638	.007	2.622	90.640	.000			
	Phenolic	6.474	.097	2.654	66.557	.000			
	Alkaloids	.757	.010	2.386	79.088	.000			

a. Wood species = Triplochiton scleroxylon
b. Dependent Variable: Abscondment

Wood species = *Khaya grandifoliola*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.436[b]	.190	-.113	23.53816

a. Wood species = khaya grandifoliola

b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1042.479	3	347.493	.627	.617[c]
	Residual	4432.359	8	554.045		
	Total	5474.838	11			

a. Wood species = khaya grandifoliola

b. Dependent Variable: Abscondment

c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	-1.845	64.322		-.029	.978			
	Flavonoid	-.065	.120	-.263	-.536	.607			
	Phenolic	.144	.631	.170	.229	.825			
	Alkaloids	.145	.141	.603	1.029	.334			

a. Wood species = khaya grandifoliola

b. Dependent Variable: Abscondment

Wood species = *Terminalia superba*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.639[b]	.408	.186	13.59468

a. Wood species = Terminalia superba

b. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1017.649	3	339.216	4.835	.019[c]
	Residual	1478.522	8	70.115		
	Total	2496.170	11			

a. Wood species = Terminalia superba

b. Dependent Variable: Abscondment

c. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	4.608	19.895		.232	.823			
	Flavonoid	.026	.057	.209	.446	.668			
	Phenolic	-.029	.008	-.350	-4.883	.002			
	Alkaloids	.065	.072	.429	.891	.399			

a. Wood species = Terminalia superba

b. Dependent Variable: Abscondment

Wood species = *Gmelina*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.849[b]	.722	.617	.58464

a. Wood species = *Gmelina*
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	7.088	3	2.363	9.763	.003[c]
	Residual	2.734	8	.242		
	Total	9.823	11			

a. Wood species = Gmelina
b. Dependent Variable: Honey yield
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	5.774	.448		12.899	.000			
	Flavonoid	.022	.003	.791	7.331	.002			
	Phenolic	.026	.002	.801	13.130	.000			
	Alkaloids	.022	.005	.617	4.464	.005			

a. Wood species = Gmelina
b. Dependent Variable: Honey yield

Wood species = *Cordia millenii*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.929[b]	.863	.812	.10695

a. Wood species = Cordia millenii
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.577	3	.192	16.829	.001[c]
	Residual	.092	8	.011		
	Total	.669	11			

a. Wood species = *Cordia millenii*
b. Dependent Variable: Honey yield
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	6.536	.251		26.029	.000			
	Flavonoid	.006	.001	1.852	4.269	.003			
	Phenolic	-.033	.006	-2.695	-5.360	.001			
	Alkaloids	-.005	.001	-1.433	-7.062	.000			

a. Wood species = *Cordia millenii*
b. Dependent Variable: Honey yield

Wood species = *Triplochiton scleroxylon*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.715[b]	.511	.328	.40825

a. Wood species = Triplochiton scleroxylon
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1.395	3	.465	2.790	.109[c]
	Residual	1.333	8	.167		
	Total	2.728	11			

a. Wood species = *Triplochiton scleroxylon*
b. Dependent Variable: Honey yield
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	8.945	3.481		2.570	.033			
	Flavonoid	-.004	.005	-.858	-.915	.387			
	Phenolic	-.087	.064	-1.755	-1.359	.211			
	Alkaloids	-.005	.006	-.750	-.768	.464			

a. Wood species = *Triplochiton scleroxylon*
b. Dependent Variable: Honey yield

Wood species = *Khaya grandifoliola*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.935[b]	.873	.826	.12045

a. Wood species = *khaya grandifoliola*
b. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	.801	3	.267	18.413	.001[c]
	Residual	.116	8	.015		
	Total	.917	11			

a. Wood species = *Khaya grandifoliola*
b. Dependent Variable: Honey yield
c. Predictors: (Constant), Alkaloids, Flavonoid, Phenolic

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	1.655	.329		5.028	.001			
	Flavonoid	.001	.001	.209	1.075	.314			
	Phenolic	.020	.003	1.856	6.297	.000			
	Alkaloids	.004	.001	1.366	5.896	.000			

a. Wood species = *Khaya grandifoliola*
b. Dependent Variable: Honey yield

Wood species = *Terminalia superba*

Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.935[b]	.875	.828	.20616

a. Wood species = *Terminalia superba*
b. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

ANOVA[a,b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	2.383	3	.794	18.691	.001[c]
	Residual	.340	8	.042		
	Total	2.723	11			

a. Wood species = *Terminalia superba*
b. Dependent Variable: Honey yield
c. Predictors: (Constant), Alkaloids, Phenolic, Flavonoid

Coefficients[a,b]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Fraction Missing Info.	Relative Increase Variance	Relative Efficiency
		B	Std. Error	Beta					
1	(Constant)	3.331	.302		11.042	.000			
	Flavonoid	-.007	.001	-.633	-7.083	.004			
	Phenolic	-.009	.003	-.452	-3.034	.016			
	Alkaloids	.006	.001	.765	5.729	.000			

a. Wood species = *Terminalia superba*
b. Dependent Variable: Honey yield