MORPHOMETRIC DESCRIPTION AND BEHAVIOURAL ECOLOGY OF *Analeptes trifasciata* FABRICIUS 1775 (COLEOPTERA: CERAMBYCIDAE) ON CASHEW (*Anacardium occidentale* LINNAEUS 1753) IN NIGERIA

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ABSTRACT

The infestation of cashew by *Analeptes trifasciata* is on the increase and this poses serious threat to cashew cultivation in Nigeria. Base-line information on the distribution and behavioural ecology of *A. trifasciata* in Nigeria is needed for its control. This study was conducted to provide more information on the morphology, distribution and behavioural ecology of *A. trifasciata* in Nigeria.

A survey of the geographical spread of *A. trifasciata* infestation was conducted in 25 cashew growing states by random sampling of 1000 trees/state from 2005 to 2006. The morphormetric and behavioural studies were carried out from 2006 to 2007. The morphometric characteristics of *A. trifasciata* were taken with a venier caliper. Monthly infestation rates of cashew trees were studied in two states (Oyo and Kogi), with high infestations. Cashew trees (300) were randomly sampled in each state to determine the number of A. *trifasciata* and girdled-tree-branches hanging or on the ground. The preferred height of girdling by *A. trifasciata* was determined by measuring infested trees with a calibrated pole, while preferred diameter of girdled-branches was determined by measuring the base of randomly collected branches. Feeding preference was investigated using stems of cashew and seven alternate host plants. These plants were placed in a feeding preference chamber at equidistance of 30 cm before the introduction of 80 pairs of males and females *A. trifasciata*. Data were analyzed with Student's t-test at $p < 0.05$.

Analeptes trifasciata was found in South-East, South-West and North-Central geopolitical zones. Pronounced infestation levels of 42.7% to 82.6% were recorded, the highest in Kogi State (82.6%) followed by Oyo State (79.3%). Adult *A. trifasciata* are large beetles, 4.0 ± 0.1 cm long. The fresh body weights of the females (3.0 ± 0.1 g) were more than those of the males (2.7 ± 0.1 g). The males possessed significantly longer antennae (6.0 ± 0.1 cm) than the females (5.3± 0.0 cm). Peak infestation (117 - 130 *Analeptes*) was recorded in September to December 2007, and least (7 *Analeptes*) in June. *Analeptes trifasciata* population was more abundant in Oyo State (554.3 ± 41.3) than Kogi State (360.7 ± 42.4). Girdled-stems hanging on tree canopies in Oyo State (546.7 ± 32.4) significantly differed from those on the ground (425.3 ± 18.2). A higher number of girdled-branches, 535.8 ± 27.6/hectare were recorded for Kogi State when

compared with 323.7 ± 18.4 for Oyo State. The beetles showed girdling preferences for moderately tall trees (2.0 to 5.0 m) and medium sized branches (4.0 to 6.0 cm diameter).

The beetles consistently fed more on cashew stems in the chamber, while *Spondias mombin* and *Lannea welwitschil* were the preferred alternate host plants.

The wide spread infestation of cashew trees in most states has made *Analeptes trifasciata* a pest of economic importance. Their large size was an adaptation for enhanced girdling, which led to significant damages in highly infested plantations. Control measures in Nigeria should target the peak periods of infestation to reduce losses in cashew production.

Keywords: *Analeptes trifasciata*, Cashew tree infestation, Girdling.
Word count: 492

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CERTIFICATION

I hereby certify that Asogwa, E. Uche carried out this work under my supervision.

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DEDICATION

Dedicated to God Almighty who used us as an instrument in His Hands to achieve this work. This work is also dedicated to my wife, daughter and to all the members of ASOGWA – OWO COMMUNION for their support.

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CHAPTER 1

INTRODUCTION

Cashew (*Anacardium occidentale)* is a member of the family Anacardiaceae, the family to which Mango, *Mangifera indica,* also belongs. The family comprises of about 60 genera and 400 species of trees and shrubs. In Nigeria, commercial plantations of cashew started simultaneously at Oghe in the then Eastern Nigeria by the Eastern Nigerian Development Corporation and at Iwo, Eruwa and parts of Upper Ogun in the present Oyo State by Western Nigerian Development Corporation (Togun, 1977). From these locations, it spread to other areas particularly the Northern States of Nigeria, but with the largest populations of about 8,000 hectares concentrated at Oghe, Mbala, Isuochi and Okigwe (Olunloyo and Igboekwe, 1985). Recent observations made from different agro-ecological zones of Nigeria showed that cashew tree is mainly cultivated by peasant farmers whose sizes of farm holdings range from 2.5 to 20 hectares. Majority of these farmers combine cashew plantings with major commodity crops like cocoa, oil palm, rubber or kola in the Southern states, while cereals and pulses are planted beneath the cashew orchards in the Northern states (Aliyu and Hammed, 2008). However, less than 20% of available cropable lands are currently being used for both food and cash crops in most of these states (CRIN, 1995; 1999; Topper *et al*., 2001).

Research on cashew production and its uses started at the Cocoa Research Institute of Nigeria (CRIN), Ibadan in 1971. Doubts exists as to the use of the word "variety" in relation to cashew, because most characteristics (size and colour of apples), which are expected in progenies raised from seeds of their tress are not easily reproducible (Akinwale and Esan, 1989).

The cashew trees are grown mainly for their kernels, which when roasted, have pleasant taste and flavour. A chocolate product called 'AMCHO', which was made at CRIN partly from cashew-kernel meal, has been organoleptically assessed to be fair for consumers' acceptability (Ojeh and Falowo, 1983). An edible oil of excellent quality has also been processed from the kernel (Ojeh, 1985). Another product from the kernel is the cashew butter, similar to peanut butter. It also finds its usage in confectionery manufacture.

Cashew nut is reported to contain the fat-soluble vitamins A, D and K. Vitamin E occurs to a level up to 200 to 210 mg/100g (Opeke, 1987). These vitamins are known to exert a sparing action on the B group of vitamins as well as assisting in the metabolism of lactose and thiamine. The nuts also contain considerable amounts of calcium, phosphorous and iron in organic complexes. The protein content varies from 20-22%. The quality approximates that of soybeans and distinctly ranks much superior to that of groundnut (peanut) (Opeke, 1987).

The cashew nut shell liquid (CNSL) is obtained from the seed pericarp by steam distillation or extraction with solvents. According to Ohler, (1979), the CNSL has found use in paint and varnish factories while the testa covering the kernel is useful in the leather industry because of its high tannin content.

The cashew apple is sweet and when fully ripe, the juice is rich in vitamin C and sugars. It contains 7 - 9 % of reducing sugars, 11-12% of soluble solids and about 0.5% of tannic acid (Opeke, 1987). In most cashew producing nations, it is eaten raw. It is a good raw material for soft drink industry. There have also been reports of jam and jelly production from the pulp following juice extraction (Ohler, 1979). The apple was also found to contain high moisture (80%) and marginal nutrient contents - protein 0.35%; ether extracts 1.8% and total ash 1.9% (Egbe and Sobamiwa, 1989).

The cashew plant is very tolerant of poor soils, low soil moisture content and low rainfall. It has proven to be a good cash crop in areas where other tree crops may have failed to be productive (Opeke, 1987). This adaptation has made the utilization of the plant for afforestation and erosion programmes popular. The plant was used extensively in the afforestation programme of areas around Udi, Nsukka, Oghe, and Oji-river in Enugu state of Nigeria.

In Nigeria, the production of cashew is impaired mostly by problems associated with its insect pest infestation. In the last twenty years, the insect pest infestation of the cashew increased year after year, and over 286 species of insect pests have been reported so far (Eguagie, 1972; 1973). However, only *Analeptes trifasciata* (stem girdler); *Selenothrips rubrocinetus* (red banded-thrips) and *Pachnoda cordata* (fruit scrapper) have been

comprehensively reported on and implicated with economic losses estimated between 52-75% of the possible production level (Ojelade, 1998).

The "longicorn" beetle *Analeptes trifasciata* Fabricius (Coleoptera: Cerambycidae) is an economic pest of cashew. Though a low-density pest, the adults have an adaptive behaviour of girdling cashew branches, which results in the death of branches from the point of girdling. The girdled stems and branches have deep grooves with thin woody tissue at the centre to temporarily support the weight of the branch. Such branches are known to snap under slight breeze, leading to loss of all the fruits the branch has yielded (Adeyemo and Okelana, 1989). Stumps of affected branches have been known to regenerate and produce many side shoots, giving an untidy appearance. Damage is usually noticed on cashew trees that have attained flowering stage.

In Nigeria, little or no importance was accorded to *A. trifasciata* in the past, but recently the attainment of economic status by the pest (Ojelade, 1998), has necessitated an urgent measure to counter its menace. Scientific information on all aspects of the pest is very scanty. Most of the available reports (Tuley and Iwenjora, 1963; Eguagie, 1972; Omole, 1980; Igboekwe, 1982; 1983; 1984; Adeyemo and Okelana, 1989; Ndubuaku, 1997) were old and not well coordinated with follow-up surveys and studies on the bioecology and control of the pest. So far no standard recommendation has been made for the control of the pest.

This study, which was carried out between 2005 and 2008 has the following objectives:

1. To determination of the distribution of *A. trifasciata* in Nigeria
2. To study the morphormetric characteristics of *Analeptes trifasciata*
3. To assess the girdling damage characteristics of *A. trifasciata* in the field
4. To determine the ecology and feeding behaviour of *A. trifasciata*

CHAPTER 2
LITERATURE REVIEW

2.1 Origin of cashew and production distribution in Nigeria

The origin of cashew has been traced to Northern parts of Brazil where the tree was considered so important that in 1641 it was legislated that any one caught cutting the tree would be penalized (Ohler, 1979). This was done to salvage it from becoming endangered by the activities of the Portuguese who were clearing large areas of land for their sugar cane plantations. They were also using its woods as fuel source for their sugar factories and breweries (Ohler, 1979). The tree was introduced into Nigeria from Northern Brazil by Portuguese explorers in the 15th/16th Century (Ohler, 1979). The Portuguese played prominent roles in the introduction of the tree into India, Central America and East Africa (Mozambique, Tanzania and Kenya in the 16th century. It is now one of the popular fruits in the Orients especially India (Ohler, 1979). The tree was reported to flourish in the wild state for a long time during which it was used mainly in afforestation schemes. Sanwo *et al*., (1972) and Togun, (1977) reported that planting of cashew tree started at Agege about the 16th century, but it was not until the early 1950's that any attention was paid to the commercial planting of the crop. It became popular in Nigeria in 1953 when it was used on a large scale in afforestation programme and in preventing erosion in the escarpment areas of Udi in old Anambra State of Nigeria.

Togun (1977) reported that commercial plantations of cashew started simultaneously at Oghe (Anambra State) in the then Eastern Nigeria by the Eastern Nigeria Development Corporation (ENDC), Iwo (Osun State) Eruwa and Upper Ogun (Oyo State) by the then Western Nigeria Development Corporation (WNDC). From these locations its planting spread to other areas particularly the central and Northern States of Nigeria. As at 1985, Enugu, Anambra and Imo States were reported to have the largest plantations of about 8,000 hectares concentrated at Oghe, Oji, Mbala, Isuochi and Kingie (Olunloyo and Igboekwe, 1985). But with the recent importation of the Brazilian nuts selections by some present day large-scale cashew farmers, the crop has spread to the Middle Belt and almost all the Northern States of Nigeria. In the past 5 to 10 years, cashew nuts has become a very important foreign exchange earning commodity crop in Nigeria with the country emerging as a leading producer in Africa and the second world producer (Azam-Ali and Judge, 2001; FAO, 2007). It

is indeed the only tree crop that is cultivated in all agro-ecological zones of Nigeria (Falade, 1978) and therefore has potentials for its large scale production.

A national cashew survey project between 1994 and 1995 revealed that apart from the old Eastern and Western regions mentioned earlier, the tree grows successfully in the Northern and Middle Belt States, indicating the distribution and cultivation in virtually all agro-ecological zones of the country including the semi-arid areas. The total land under cashew tree cultivation in Nigeria by 1995 was estimated at about 40,000 hectares, of which about 60% of the holdings were owned by peasant farmers (Ayodele *et al.*, 2001).

Another survey jointly carried out in the year 2001 by the Cocoa Research Institute of Nigeria and the BioHrybrids Agri-System (Consultants) of Great Britain; revealed that much more hectarages of cashew plantations had been established between 1995 and 2000 (Topper *et al*., 2001). Many more state governments had shown impressive interests in the cultivation of the crop, notably Cross River, Edo, Ekiti, Lagos, Nassarawa, Ogun, Ondo, Osun and Plateau states through the cashew production expansion programmes of various Agricultural Development Project (ADPs), National Land Development Agency (NALDA), and Tree Crop Units (TCUs). In addition, over 2 million nuts and 50,000 seedlings of improved planting materials were distributed to farmers (government, corporate and peasant farmers) by the Cocoa Research Institute of Nigeria during this period (1995 to 2000).

The total land under cashew tree cultivation in Nigeria by 1990 was estimated at about 50,000 hectares, of which about 60% of the holdings were owned by peasant farmers (Ayodele *et al*., 2001). Currently, the total land area under cashew cultivation has increased from 175,000 hectares in 1996 to 320,000 hectares by 2006 (FAO, 2007). The cashew nut production has been on steady increase from 30,000 metric tonnes in 1990 to 636,000 metric tonnes in 2006 (FAO, 2007) (Table 2.1). This significant increase has been due mainly to the involvement of private entrepreneurs, Federal and State Governments, Cooperative societies and affluent farmers in cashew cultivation (Aliyu and Hammed, 2008). The introduction of Brazilian cashew biotype with improved and desirable nut and kernel quality characteristics by the Cocoa Research Institute of Nigeria (CRIN) has further increased the crop's spread and popularity in Nigeria (Hammed *et al*., 2007). There has also been a tremendous price appreciation of Nigerian cashew nuts in the international markets with a tonne of

cashew nuts, which sold for N24,753.00 in 1993 rising to N180,011.00 in 2003 (FAO, 2007).

Table 2.1: Cashew nut production in Nigeria 1990 – 2006

Year	Ann Prod.'000 tons)	kg/ha '000ha	Harvested area	Price/ton (N)
1990	30.00	600.00	50.00	-
1991	45.00	600.00	75.00	10,700.00
1992	55.00	611.10	90.00	15,677.00
1993	75.00	625.00	120.00	24,753.00
1994	85.00	629.00	135.00	36,335.00
1995	95.00	612.90	155.00	62,415.00
1996	110.00	628.60	175.00	81,872.00
1997	125.00	514.40	243.00	88,601.00
1998	152.00	625.00	243.20	94,175.00
1999	417.00	1,752.10	248.00	92,662.00
2000	466.00	1,799.20	259.00	97,407.00
2001	485.00	1,830.20	265.00	24,698.00
2002	514.00	1,882.80	273.00	150,636.00
2003	524.00	1,891.70	277.00	180,011.00
2004	555.00	1,900.70	292.00	
2005	594.00	1,922.30	309.00	
2006	636.00	1,990.0	320.00	

Source: FAO, 2007. http://faostat.fao.org/site/336/DesktopDefault.aspx?PageID=336

2.2 Economic importance of cashew

All parts of the cashew tree are of economic importance, although it is grown primarily for its fruits (nut and apple), and secondarily for landscaping and control of erosion. Its earliest use in Nigeria was for afforestation and control of soil erosion, which had been a serious problem in some of the high rainfall areas, characterized by sandy soils in the country (Togun, 1977). The effectiveness of the tree in this respect is due to its large crown diameter and close canopy to intercept rain showers and extensive root system, which holds the soil particles together thus, reducing their susceptibility to erosion (Akinwale, 1995). The tree grows well in sandy places, and has been satisfactorily used for reclamation of sand dunes near the sea (Dalziel, 1937, Roservear, 1961). The introduction of Brazilian cashew biotype with improved and desirable nut and kernel quality characteristics by the Cocoa Research Institute of Nigeria (CRIN) has further increased the crop's spread and popularity in Nigeria (Hammed *et al*., 2007). The various utilization of parts of the cashew trees are reviewed below:

2.2.1 The cashew apple

The apple has been made into jam, juice and good quality wine. During the fruiting season, the apple is sold in the market unprocessed for consumption. In Senegal, it has been sundried and used in preparation of syrup that is enclosed with attributes of general panacea, an aphrodisiac, stimulant, strengthener and elixir of longevity (Kerharo and Adam, 1962). The pulp is a potential source of alcohol, and it has been used to make vinegar (Watt and Breuyer-Brandwijk, 1962). The distilled spirit from apple has been found to be diuretic and rubefacent (Quisumbing, 1951). At Cocoa Research Institute of Nigeria, it has been utilized for the manufacture of fruit juice, vinegar, jam, top quality sweet wine (8-12% v/v alcohol), dry wine, gin and brandy (17-18% v/v alcohol). In spite of this effort, Nigeria is yet to establish an industry that can wholly take up the utilization of cashew apples; hence much of the present production is left to waste.

It has been estimated that more than 3,000 metric tonnes of apples became wasted annually from cashew plantations (824ha) in Oyo State alone, implying that an estimated quantity of about 360,000 metric tonnes of apples are wasted from the current national estimated total hectarege of 70,000 to 100,000 hectares (Togun, 1977). According to

Morton (1987), cashew apple juice, without removal of tannin, is prescribed as a remedy for sore throat and chronic dysentery in Cuba and Brazil. Fresh or distilled, it is a potent diuretic and is said to possess sudorific properties. The brandy is applied as a liniment to relieve pain of rheumatism and neuralgia.

The cashew apple juice is used for the production of bioethanol, candy, jam, chutney, carbonated beverages, sirup, wine and viniger in India. In Goa, it is used for the brewing of a famous locally distilled liquor "feni", while in Brazil it is used for making fresh beverage and wine (Morton, 19987; Neelakandan and Usharani, 2009; Thiripurasundari and Usharani, 2011).

2.2.2 The cashew nut shell

The shell of the nut contains a non-edible, acidic, and resinous oil called Cashew Nut Shell Liquid (CNSL). The oil is composed of appropriately 82% anacardic acid, 13.8% cardol, 2.6% 2-methyl cardol and 1.6% cardanol; all these constituents are vesicant poisons that blister the skin. CNSL is an excellent monomer for polymer production (Pillai *et al*., 1990; George and Pillai, 1992). With technological advancement, CNSL is used as wood and fabric preservatives and in the manufacturing of paints, plastics, printing ink, germicides, insecticides, water proofing compounds, synthetic resins, and dyes as anti-fade agents in brake lining and clutch facings of motor vehicles (Woodroof, 1967). Varied number of resins has also been synthesized from CNSL, which can be used as fillers for paints, vanish, and adhesives (Gowri and Saxena, 1997; Ghatge and Malodor, 1981; Menon *et al.*, 1998). CNSL is also endowed with special attributes of physical and chemical characteristics that enable it to serve as brake fluid due to its viscosity and high level of unsaturation.

2.2.3 The cashew nut kernel

The roasted kernel, which is mostly used as a dessert is the main commercial product of cashew. It is also used in confectionery and bakery (Woodroof, 1967). Cashew butter, which is similar to peanut butter, is also made from broken nuts (Ohler, 1979), while the crumbs and husks are useful as animal feeds (Fetuga *et al*., 1975). At CRIN, quite a good number of uses of the product and by products have been developed.

The edible cashew kernel oil, golden-yellow in colour and of excellent quality, has been found highly stable and promising for various food and industrial applications (Falade, 1972; Ogunmoyela and Ukhum, 1982). The cashew nut meal obtained as residue has been reported to have high protein content of 40% useful for enriching or fortifying our local foods. Cashew meal coated chocolate product has also been developed at CRIN and its organoleptic properties had been assessed to be acceptable to consumers. Protein concentrates and isolates in addition to high quality cashew-nut butter has been extracted from the nuts (Ogunwolu *et al*., 2010a; 2010b).

2.2.4 The cashew leaves

The young leaves are eaten in South East Asia (Burkill, 1935). Mature leaves are rich in tannin (25%) and are used for their astringent properties as in the bark. The Aku (Yoruba) people of Sierra Leone used the young leaves for dysentery, diarrhoea and hemorrhoids (Dalziel, 1937). A yellow dye extracted from the leaves is used for dyeing fishing nets in Senegal (Irvine, 1961).

2.2.5 The cashew stem

The stem is useful in various construction works, and the wood is used in boat building, packaging cases and in the production of charcoal. It is also used in production of chests, mortars, house and fence-posts and firewood (Dalziel, 1937).

2.2.6 The cashew bark

The bark has astringent properties. It contains 9-21% tannin and is used in tanning (Walker and Sillans, 1961). Bark and leaf infusions are used to relieve toothache, and sore gums and are taken internally for dysenteric condition (Kerharo and Adam, 1962). The bark has also been used in treating "Efu", symptomized by a white tender tongue and a more serious condition with a black tongue "Kolobo or Ishanu (Ijebu)" (Burkill, 1935). In Congo, a bark-infusion is taken for urethra discharge and with *Manikara obovata* (S*apotaceae*) a decoction used to treat women's menstrual pains (Bouquet, 1969). Oral administration of extract of bark was found to lower blood sugar level within 15 minutes of ingestion (Kerharo and Adam, 1962). In Brazil, the bark had been used to lower blood

pressure (Chopra *et al*., 1956), used as anti-malaria, for fever treatment (Wren, 1959) and as antidotes for snakes' bites (Dastur, 1952). The bark also contains a gum known as cashew gum, which is bright yellow to dark brown in colour. It has been used in South America as a bookbinding gum in the place of acacia gum (Watt and Breyer-Brandwijk, 1962). The sap from the bark is also known to contain cardol and it has been used in the treatment of leprosy and also used as wood preservative against decay and termites (Kerharo and Adam, 1962).

2.3. Nutrient and chemical composition of cashew

The cashew apple contains 85% juice, 10% sugar, riboflavin, minerals and several times as much vitamin C as in citrus fruits (Akinwale and Aladesua, 1999). The non-alcoholic beverage is of a high nutritional value (Vitamin C of 170-180mg/1000ml). Murthy and Yadava (1972) reported that the reducing sugar content of the kernel varied from about 1 - 3% and the non-reducing sugar from 2.4 - 8.8%. Starch content was found to range from 4.6 - 11% and the oil content of between 34.5 and 46.8%. Mahendru (1976) reported that cashew kernels contain about 0.8 - 1.4mg of thiamine per 100g and 0.58mg riboflavin per 100g. However, according to Fetuga *et al.,* (1975), there are reported variations in the mineral content of the kernel collected from different cashew trees.

Lopez (1972) analyzed red and yellow apples from various parts of Mozambique. The greatest variability was found in the tannin content, the lowest being 0.06g and the highest 0.22 per 100g, and pH of the apples varied between 4.1 and 4.7 and total sugar from 6.7 - 10.5%. The vitamin C content ranged from 234 - 371mg per 100g.

The cashew apple juice though sweet and nutritious, has astringency, which makes it less palatable. The phenolic compounds present in the apple are mostly responsible for the astringency of the juice. According to Ohler (1988), cashew apple is a tropical fruit rich in vitamins and minerals. It contains 0.099% Vitamin B_2, 0.24% Vitamin C, 0.041% Calcium, 0.011% Phosphorous and 0.003% Iron. Indeed, the Vitamin C content of cashew apple is almost ten (10) times more than that of pineapple, a customary tropical fruit. As cashew apple has a very low content of carbohydrates,

almost as low as 1% soluble sugar, the consumer of cashew is privileged to get a sweet taste without having to worry about excess calories.

The kernel, which is a component of the nut, is considered to be of high nutritional value (Babatunde and Oyenuga, 1974; Joseph, 1975). Nayar (1997) reported that cashew kernels are excellent dietary supplement to the human diet, containing 3.39mg/100g of amino acids, and a ratio of 1: 2: 1 of saturated: mono unsaturated: polyunsaturated fats. Cashew kernel is a unique combination of fats, proteins, carbohydrates, minerals and vitamins. It contains 47% fat, but 82% of this fat is unsaturated fatty acids (Nayar, 1997). The unsaturated fat content of the kernel not only eliminates the possibility of the increase of cholesterol, but also balances or reduces the cholesterol levels in the blood. Cashew kernel also contains 21% proteins and 22% carbohydrates and the right combination of amino acids, minerals and vitamins and therefore nutritionally, it stands at par with milk, eggs and meat. Cashew kernels do not lead to obesity and help to control diabetes. It is good appetizer, an excellent nerve tonic, and a stimulant and body builder.

2.4 Bio-ecology and pest status of major insect pests of cashew

In Nigeria, the production of cashew is impaired mostly by problems associated with its insect pest complex. In the last twenty years, the insect pest complex of cashew increased year after year. However, only *Analeptes trifasciata* (the stem girdler); *Selenothrips rubrocinetus (*red banded thrips*) and Pachnoda cordata* (the fruit scraper) have been implicated with economic losses estimated between 52-75% of the possible production level (Ojelade, 1998).

Cashew, like most tree crops hosts a wide range of pests and diseases. Insect pests infest its various parts including roots, stem, branches, flowers, inflorescence and the psuedo-apples. Earliest work on Cashew-Entomology carried out at CRIN involved the collection, identification and preservation of the insect pest complex of the cashew plant. Seven main orders (Lepidoptera, Coleoptera, Orthopthera, Hemiptera, Hymenoptera, Thysanoptera and Isoptera) were reported in the research study (Eguagie, 1972; 1973; 1974). The occurrence of *Dysdercus superstitious* (cotton stainer) and *Leptoglosus*

membranaceus as new pests of cashew was observed in 1988 (Olunloyo, 1989), thus indicating an increase in the number and species of insects infesting cashew plantation with time. However, Omole (1972) observed that only a few of these insect species cause economic damage to this crop. These insect pests were classified into major and minor pests depending on the degree of their devastating effects and also based on the parts of cashew plant infested (stem, fruits, shoots, leaves or roots) (Table 2.2).

Table 2.2: Insect pests associated with Cashew in Nigeria

Pest specie(s)	Common name	Affected parts	Pest Status
Analeptes trifasciata Fabricius (Coleoptera: Cerambycidae).	Stem girdler	Stems	Major pest
Plocaederus ferrugineus L. (Coleoptera: Cerambycidae).	Root and trunk borer	root/trunk	Major pest
Pachnoda cordata Drury (Coleoptera: Scarabidae)	Fruit scraper	Fruits	Major pest
Selenothrips rubrocinctus G. (Thysanoptera: Thripidae)	Red-banded thrips	Shoot/leaves	Major pest
Zonocerous variegatus Linn (Orthoptera: Acrididae)	Grasshopper	Leaves/fruits	Minor pest
Oecophylla longinoda Latl (Hymenoptera: Formicidae)	Tailor ant	Leaves	Minor pest
Apis mellifera (Hymenoptera: Apidae)	Honey bee	Flower/fruits	Minor pest
Camponotus spp (Hymenoptera: Formicidae)	Ant	Leaves	Minor pest
Atopomyrimex spp (Hymenoptera: Formicidae)	Ant	Leaves	Minor pest
Macrotermes natalensis (Isoptera: Termitidae)	Termites	Shoot/roots	Minor pest
Nasutitermes spp (Isoptera: Termitidae)	Termites	Shoot/roots	Minor pest
Acrecercops synagramma M. (Lepidoptera: Lithocolletidae)	Leaf miners	Leaves	Minor pest
Anapleocnemis curvipes Heteroptera: Coreidae	Fruit scraper	Fruits	Minor pest
Euprotis fasciata Wlk. (Lepidoptera: Lymantriidae)	Leaf roller	Leaves	Minor pest
Achaea lienardi Boisd. (Lepidoptera: Noctuidae)	Fruit piercing moth	Fruits	Minor pests
Dysdercus superstitiotus (Heteroptera: Pyrrhocoridae)	Cotton stainer	Fruits	Minor pest
Drosophila spp (Diptera: Drosophilidae)	Fruit fly	Fruits	Minor pest

Source: Modified from Eguagie, 1972; 1973; 1974; Omole, 1977a; 1981; Igbokwe, 1984; Adeyemo and Okelana, 1989

2.4.1 Cashew stem girdler (*Analeptes trifasciata*) Coleoptera: Cerambycidae

In Nigeria *Analeptes trifasciata* damage was reported by Tuley and Iwenjora, (1963) to be identical to a beetle called *Paranaleptes reticulata* (Thomson) Cerambycidae, which is also called the "cashew stem girdler". It is a major pest of cashew in Kenya and Tanzania (Jones, 1961; Hill, 1975). *Analeptes trifasciata* is a low-density pest. The adults have an adaptive behaviour of girdling cashew branches, which results in the death of the branches from the point of girdling. The symptoms of damage by *Analeptes trifasciata* include the presence of small holes and girdled portions on stems and branches. Such affected stems and branches have deep groves as a result of which the stems and branches are left with thin woody tissue at the centre to temporarily support the weight of the branch, leading to the sudden snapping of such branches (Ohler, 1979; Igboekwe, 1982). The stumps of infested stems and branches sometimes regenerate and produce many side shoots giving an untidy appearance. Damages are noticed on cashew trees that are four or more years old (Brunck and Fabre, 1970). In Nigeria, damages by the stem girdlers, *A. trifasciata*, is estimated between 53 - 75%, while factors such as the proximity of the cashew trees to the forest, canopy within the plantations, the height of the girdled branch and its diameter were reported to contribute significantly to the level of damage on the field (Ndubuaku, 1997).

The cashew stem girdler, *Analeptes trifasciata* is an important pest of cashew and is widely distributed in Nigeria covering the Savannah and rain forest regions. They may be found in relative abundance in forest fringes where members of the family Anacardiaceae grow. The abundance of adult *A. trifasciata* varies from place to place at certain seasons of the year. According to Eguagie (1972) and Omole (1980), the pest abounds on cashew at Eruwa and Idi-Ayunre areas of Ibadan in Oyo state. Studies carried out by Igboekwe in 1982 and 1983 showed that this pest occurs and causes damage to cashew in Enugu, Anambra, Imo, Abia, Edo, Delta, and Kogi States of Nigeria. He reported that this pest though a low-density pests, shows two peaks in a year. The adults are seen in cashew plots around May with their number building up to a peak between June and July after which it declines. A second, but higher peak in population was observed again in November of the

same year. This population pattern of the pest has also been observed at Cote d' Ivoire and Ghana (Brunck and Fabre, 1970; Atuahene, 1977).

Igboekwe (1982; 1983; 1984) showed that during breeding season, October-January, the adults of the cashew stem girdler *Analeptes trifasciata* move in pairs on cashew trees and both male and female participate in girdling cashew branches. According to Adeyemo and Okelana (1989), the female beetle lays its eggs above the girdled portion in excavated holes made on the bark of the branch with her ovipositors. The eggs are laid singly above the girdled point on the branch. They are elongated and 0.15cm in diameter. It has been found that a heavily infested branch could contain up to 80 eggs (Igboekwe, 1982). The emerging larvae burrow into the stem for further development. While developing and moulting within the infested stem, larvae feed on vascular tissues, block the translocation of plant sap, thus, leaving a thin layer of woody tissue at the centre which snaps off eventually at the slightest blow of the wind. The number and duration of the larval instars as well as the pupal period are not yet known. The emerging adults eventually re-infest cashew trees in the plot.

2.4.2 Red banded thrips (*Selenothrips rubrocinctus*) Thysanoptera: Thripidae

Selenothrips rubrocinctus, the red-banded thrips, have been observed as important foliage pest of cashew, causing severe damage to young cashew plantations most especially during drought or dry seasons (Omole, 1977b). According to Cavaloante (1975), the adults and immature stages (nymphs) of *S. rubrocinctus* colonise the lower surface of leaves. The leaves become pale brown and slightly crinkled with roughening of the upper surface as a result of their feeding and sucking activities. Heavily attacked leaves fall off and the defoliated branches give the tree the characteristic stag-headed appearance. The plants that survive normally become stunted in growth. Although they seem to have a slight preference for the older leaves, the species also attack young leaves, shoots, inflorescence and flowers.

Eguagie (1972) observed two peak periods of the red-banded thrips *S. rubrocinctus*, occurring from July - August and early dry season, November - December respectively,

while Omole (1977b) observed a slight difference in the periods of peak population as between February - May and between September – November, suggesting that these periods depend on the time the host plant is most attractive for the reproduction of the pest.

Adeyemo and Okelana (1989) noted that the adult thrip of the cashew, red-banded thrips, *S. rubrocinctus*, are very tiny, being about 1.5mm and black in colour with fringed or feather-like wings. The nymphs are yellow with their first abdominal segment being red in colour. The female thrips lay their eggs singly on the underside of leaves and cover them with small black spots of excreta or frass. The eggs of the red-banded thrips (*Selenothrips rubrocinctus*) are kidney-shaped and about 0.25mm long. The female inserts them into the leaf tissue. Hatching occurs in 12-18 days and the nymphs develop over the next 6-10 days. The pupae resemble the nymphs but have wing buds and do not feed, but will move when disturbed. The adults emerge after 3-6 days (NRI, 1996).

2.4.3 Leaf roller (*Euprotis fasciata)* Lepidoptera: Lymantriidae

The symptoms of infestation by the *Euprotis fasciata* are defoliation and presence of rolled leaves, which eventually dry up, and fall off (Adeyemo and Okelana, 1989). The pest is commonly found during early part of dry season in all cashew producing zones. There have not been any conclusive studies of the biology of this pest in Nigeria.

2.4.4 Pseudo-Apple scrapper (*Pachnoda cordata*) Coleoptera: Scarabidae

The cashew pseudo-apple scraper, *Pachnoda cordata*, feeds on the buds, blossoms, leaves, and mostly fruits of cashew. By their feeding activities they destroy the cashew apple and cause them to rot and fall down from the tree. The fermentation of these rotten apples also attracts the fruit fly *Drosophila* spp (Diptera: Drosophilidae) that also cause damage to cashew psuedo-apple (Adeyemo and Okelana, 1989; Ojelade, 1998).

The pest is well distributed in Nigeria and attacks other crop like maize, where it feeds on maturing and ripening maize ear.

According to Adeyemo (1988b), the larva of the cashew pseudo-apple scraper *Pachnoda cordata* is a white grub and is primarily fossorial. The eggs are laid in the soil and hatch in 4 – 8 days. It has 4 - 5 larval instars, followed by a pupal stage. The longevity of the larvae is between 26 – 38 days, while pupation takes 87 – 204 days before adult beetle emergence.

2.4.5 Grasshopper (*Zonocerous variegatus*) Orthoptera: Acrididae

Adeyemo (1988a) reported that the nymphs and adults of the grasshopper, *Zonocerous variegatus* attack young seedlings and ripe cashew fruits. The adults have been observed to scrape the fruit wall of the ripe fruits. In most cases, there was always a thin layer left before the juicy part of the fruit. Such thin layers and rotting pseudo-apples were subsequently pierced by the fruit fly - *Drosophila* spp and the bees, *Apis mellifera* in search for the juice of cashew. The nymphs of the variegated grasshopper *Z. variegatus* are gregarious and often very numerous and it is at this stage that most damages are done. They are sluggish and migrate only slowly by walking and hence attack tends to be patchy. The adult grasshoppers are less gregarious than the nymphs, which eat up the leaves especially those of seedlings, leaving the veins intact. Both the nymphs and adults feed on new flushes, moving from one plant to the other. Their feeding activities always result in severe damages to young cashew stands.

The variegated grasshopper, *Zonocerus variegatus* L. is widespread throughout West Africa, south of the Sahara spreading eastwards as far as Uganda and northwards into Sudan (Page, 1978). Youdeowei (1974) has produced a map of the distribution of the two species of *Zonocerus* (*Z. variegatus* and *Z. elegance)*, which occur in Africa. Youdeowei (1974) and Page (1978) showed that *Z. variegatus* is largely distributed between the Tropic of Cancer and the Tropic of Capricorn, with a predominant occurrence in the West African sub region. In Nigeria, Toye (1971) has shown that *Z. variegatus* usually occurs in cultivated land with nymphs and adults sharing the same habitat and its habitat extend from the lowland Rain forest zone to the Guinea savannah in the north. Two distinct populations of *Z. variegatus* exist in southern Nigeria (Golding 1940; 1948; Oyidi, 1966; 1967; 1968;

Toye, 1971; Taylor, 1972; Anya, 1973 and Youdeowei, 1974). These are typically referred to as the dry and wet season populations. In the Ibadan area, populations of *Z. variegatus* can be found throughout the year. The population found during the wet season (April – October) is small, while the dry season population (November –March) is usually larger in size (Page, 1978).

In Western Nigeria, adult *Z. variegatus* become sexually mature with the onset of the rains. Their eggs are laid from the middle of March to April, with the majority of the laying occurring during the first week in April, but do not hatch until late October or November with delayed embryonic development, which includes diapause taking 6-7 months (Entwistle, 1972; Page, 1978; Omole, 1986). In Eastern Nigeria, there is one annual generation but two definite broods, most eggs being laid in March/ April and August/September (Jerath, 1965). Each female lays 1-4 egg pods, which is 40-45mm long, each containing 20-90 eggs. The pods are buried 5-8cm deep in the soil. As many as 3,500 pods have been found in a site of $16m^2$ (Toye, 1982). This shows that egg pods are normally concentrated in selected egg-laying sites. COPR (1976) suggested that odours of laid eggs attract female to the egg-laying sites. The egg development is dependent on high level of soil moisture and takes place at the end of the wet season. *Z. variegatus* generally has six nymphal instars in the field although a small percentage of the insects will have only five instars (Chapman *et al*., 1977). The nymphal development proceeds during the dry season and adults are dead before the next rain or at the onset. (Entwistle, 1972; Toye, 1982).

2.4.6 Termites (*Nasutitermes* spp) Isoptera: Termitidae

Termites attack on cashew is wide spread both in the nursery and plantations, where the taproots and the basal portion of the stems are usually attacked (NRI, 1996; Topper, 2002) . Many termites make narrow covered runways, or shelter tunnels from subterranean nest up to the trunk to suitable tissues on the tree. The 'runs', which can be regarded as nest extensions, may be constructed of particles of earth or of chewed wood and lead to death of the stems and branches. Such runways are a common feature of cashew plantations. In

Nigeria, cashew plantations, seedlings and stems of mature trees are ring-barked by these termites. This starts at soil level and may extend upwards to 60cm and occasionally damage has been seen as high as 5m. Most damages are prevalent where litter accumulates close to trunks or where mulches are applied. It is usually first observed at the beginning of the rain (Kay, 1960).

Lee and wood (1971) stated that as plant tissue was either directly or indirectly the source of food for termites, vegetation must be an important factor in determining their distribution and abundance. Termites are found all year round. In Nigeria, various species have been reported to cause serious damage on virtually all the economic crops across the Mangrove and fresh water swamp forest, Rain forest, Guinea savannah and Sudan savannah. (Sands 1962; Harris, 1971; Malaka, 1973; 1983; 1996).

Termite colonies are started by the sexual reproductives, which fly from the nests at the start of the rainy season and loose their wings before re-entering the soil or other hiding places. The sexes meet either in the air or on the ground and males are attracted to the females by pheromones. Courtship in termites includes the trend of events from pairing to excavation of the initial cell where copulation is eventually accomplished and eggs laid. In an established colony the queen lays eggs, which are coated, in an attractive liquid, which the waiting workers drink. The eggs may be carried by the workers in their mouth-parts (Palp and Jaws) to other chambers or to a separate part of the royal chamber. They are often held together in a pile by salivary secretions, but may be moved around for cleaning by the workers. The larvae are translucent with large setae. They can be assisted in hatching by workers who pull off, eat the eggshell and clean the larvae thoroughly to remove any remains. The larvae on hatching remain in the brood chamber with the reproductives that look after and clean them, until the first workers develop to take on the role of foraging for food and looking after the young ones. Since termites undergo incomplete metamorphosis, even the younger instars of their nymphs greatly resemble the adults and take on important functions in the nest at an early stage (Kranz *et al.*, 1978; Malaka, 1996; Pearce, 1997).

2.4.7 Cotton stainer (*Dysdercus* spp.) Heteroptera: Pyrrhocoridae

The adults and nymphs of cotton stainers, *Dysdercus superstitiosus; Dysdercus fasciatus,* feed on seeds by sucking sap through the walls of cashew fruits. They may attack all stages of fruit development. Damage caused is most serious on younger green fruits, which may turn brown and become distorted in shape, but are not shed. The fungus *Nematospora gossypii* that is transmitted to the pseudo-apple through the insect mouthparts as it feeds may also cause serious damage. The fungus causes fruit rotting which can completely destroy young fruits or sections of ripe fruits (NRI, 1996).

This is a major and common pest throughout Nigeria. They abound in areas where crops like cotton; kenerf, okra, sorghum and millet are grown. The adult female of cotton stainer, *Dysdercus superstitiosus* lays eggs in batches of up to 100 in damp soil or plant debris under the host plant. The eggs are ovoid, 1.5mm in length and yellow in colour when first laid but later turn darker. Hatching occurs between 4 – 13 days and there are five nymphal instars, which last a total of about 25 days. The first instars do not feed and cannot be seen clustered around the eggshells. The second and third instars feed on cotton seeds near to the ground. Later instars can be found on seeds over the whole plant. Females can lay 800 – 900 eggs in their 60-day life span (NRI, 1996).

2.4.8 Ants (*Camponotus* spp; *Oecophylla longinoda; Atopomyrmex* spp) Hymenoptera: Formicidae

Ants are generally nuisance pests, building nests in trees, biting aggressively and making harvesting difficult. Some ants like tailor ant, *Oecophylla longinoda* (Hymenoptera: Formicidae) are known to weave cashew leaves to build nests and scale insects are sometimes harbored in the nests thereby protecting them from the effects of insecticides and other natural enemies. Other species such as the *Camponotus* spp and *Atopomyrmex* spp are also found on cashew trees. They are dissemination agents of some pathogens and also effective agents of inoculation (Olunloyo, 1978; 1989). The various ant species are found to

be associated with cashew and other related plants wherever they are grown. The biology of the various ant species associated with cashew have not been well documented.

2.5 Control of cashew pests

The cashew insect pests can be controlled by various methods, which includes cultural/physical control, use of alternative hosts and chemical control.

2.5.1 Cultural and physical measure

Based on the knowledge of the nature of damage and oviposition sites of *A. trifasciata*, Brunck and Fabre (1970) and Igboekwe (1982) suggested the use of farm sanitation method for the control of this pest. Farm sanitation involves the removal of girdled stems containing the eggs and progenies of the pest from the plantation and destruction of developmental stages inside them by burning such stems outside the plantation. Regular clearing of plantations is also advocated. Studies by Igbeokwe (1987) on the control of this beetle through farm sanitation methods in cashew plantations at Onigambari showed that the percentage of infested trees in a cashew plot was reduced from 20.99% to 7.17%. These farm sanitation/cultural methods can be effectively utilized for all the major and minor pests of cashew.

A drastic reduction of the *Zonocerus* population could be achieved by digging up the egg pods in the egg laying sites and exposing them to their high surface temperatures so that the eggs are killed. If all or nearly all the sites in a large area are cleared in this way the population of the grasshoppers can be reduced well below the damage threshold at no financial cost and with very little labour (Page, 1978; Toye, 1982). According to the COPR (1977), it is possible to reduce a *Zonocerus* population by 90% through this method. Also, studies carried out in two egg- laying areas (Page 1978) showed that potential hatches were reduced by 83-91% respectively through exposure of dug up egg pods to desiccation. This however requires that the farmers identify the sites.

Cultural control of termites in cashew plantations could be effectively achieved by: (i) Prevention of root, collar and basal stem attack in the nursery and in young plants in the field.

(ii) Prevention of termite establishment in wounds and dead wood on mature trees so as to avoid spread of infestation to healthy wood. In this case treatment should be an organized part of routine farm or plantation maintenance and consists of careful pruning of dead wood, preferably with saw cuts close to the branch origin, and treatment of cut and damage surfaces with a copper fungicide until they are callused over.

(iii) Heavy watering of root ball during the dry season will reduce incidence of termite attack (NRI, 1996).

2.5.2 Use of alternative hosts

Studies by various scientists have produced a long list of alternate-host plants of cashew pests. These include; *Lannae humilus* Oliv (Anarcardiaceae) S*pondias mombin* L. (Anacardiaceae), *Terminala catappa* (L) (Combretaceae) *Ficus mucosa* (Moraceae) *Theobroma cacao* (Sterculiaceae), *Eucalyptus alba* (Myrtaceae) *Eucalyptus toreticornis* (Myrtaceae), *Adansonia digitata* (Borabacaceae), *Manihot esculenta* and *Ceiba pentandra* for *Analeptes trifasciata*. For *Selenothrips rubrocinctus* we have *T. cacao* and areca nut or betel nut (Areca tree), while pawpaw, mango, almond and citrus trees are notable alternate hosts for *Pachnoda cordata* (Eguagie, 1972; Atuahene, 1977; Akanbi, 1979; Igboekwe, 1982; 1984; Adeyemo and Okelana, 1989). These host plants, excluding *T. cacao*, can be manipulated in trapping out the pests away from the cashew plantation.

2.5.3 Chemical control

Chemical control method involving the use of insecticides remains the only effective method so far reported for controlling the cashew red-banded thrips, *Selenothrips rubrocinctus.* It involves spraying thrice a year in January, October, and November with 0.05% Dimethoate or Rogor (Omole, 1977b). Recent research activities

are on the use of alternate insecticides such as Basudin 600 E.C. (0.25% a.i.) and Cymbush 10 E.C (0.5% a.i) for the control of *Analeptes trifasciata*.

All instars of *Zonocerus variegatus* can be killed easily by the common insecticides (Fenitrothion) using solutions of 0.1% w/v. a.i. The best time for spraying is early in the morning or late afternoon when the insects are less active and preferably on the highly aggregated early instar nymphs of the insect. However, due to the dispersal and high mobility of later instars of the insects spraying them would be uneconomical unless the crop is of high economic value, in which case spraying at regular intervals according to the rate of re-invasion, would be worthwhile (Page, 1978; Toye, 1982).

Termites could be effectively controlled by the application of persistent insecticides (Methidathion, Carbofuran, Endosulfan, Pyrinex, Dursban, Termicid, Endocap and Fenitrothion to the soil around the base of the cashew seedlings and mature plants just before the onset of the dry season (NRI, 1996; Adejumo and Asogwa, 2001).

The economic injury level for thrip infestation is 240 thrips per plant on six-week-old plants. At this point Dimethoate solution can be applied three times during the dry months (January, October and November) to control infestation, while the cotton stainer, *Dysdercus superstitiosus* could effectively be controlled by the use of Endosulfan, Pirimiphos-methyl, Lambdacyhalothrin and Fenitrothion (NRI, 1996).

CHAPTER 3
MATERIALS AND METHODS

3.1. Research and survey locations

These studies were carried out at the Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan, CRIN substation, Ochaja and in cashew plantations within the Federal capital Territory and twenty five (25) States of Nigeria.

3.1.1 Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan

The Cocoa Research Institute of Nigeria (CRIN), Onigambari experimental station, Ibadan, Oyo State (Table 3.1, Fig. 3.1a) is located within latitude 7^0 10' N and longitude 3^0 52' E, at an altitude of 122m above sea level. The climate is characterized as tropical with two distinct seasons (dry and wet seasons). The dry season runs from early November to March while the wet season starts from end of March to November. The total annual rainfall is between 1300mm to 2500mm with two peaks in June/July and September/October. The minimum temperature is between 18^0C and 21^0C while maximum temperature ranges from 30^0C to 32^0C. The relative humidity (RH) is uniformly high (100%) at night and falls to between 70% and 80% during the daytime; and sometimes reduces further during the dry season (Adeyemi, 1999; Famaye, 2000; CRIN, 2007).

3.1.2 Cocoa Research Institute of Nigeria (CRIN) substation, Ochaja

The Cocoa Research Institute of Nigeria (CRIN) Sub-station, Ochaja in Ayangba, Kogi State (Table 3.1, Fig. 3.1b) is located within latitude 7^0 15' N and 7^0 30' E, at an altitude of 620m above sea level. The climate is characterized as tropical with characterized as tropical with two distinct seasons (dry and wet seasons). The dry season runs from late October to early May while the wet season starts from May to October. The total annual rainfall is about 1100mm with a major peak in July. There is usually a two week dry spell in August. The atmospheric temperature ranges between 23 ^{0}C and 34^0C, while relative humidity ranges between 50% and 70% throughout the year (CRIN, 2007; Hammed, 2008).

Table 3.1: Cashew research plots at CRIN headquarters, Ibadan and Ochaja substation

S/n	Name of plot	Code	Year	Planting distance	Selections (variety)
CRIN headquarters, Ibadan					
1.	North plot 7/3	N7/3	1973	6.2 m x 6.2 m	Mixed collections
2.	South West plot 3/2	SW3/2	1974	6.2 m x 6.2 m	Mixed collections
3.	South South plot 6	SS6	1974	6.2 m x 6.2 m	Mixed collections
CRIN Ochaja substation					
1.	North West plot 1	NW1	1976	6.2 m x 6.2 m	Mixed collections
2.	North West plot 7	NW7	1976	6.2 m x 6.2 m	Germplasm collection
3.	South East plot 5^{A}	SE5A	1976	9 m x 9 m	Oro small sized nuts

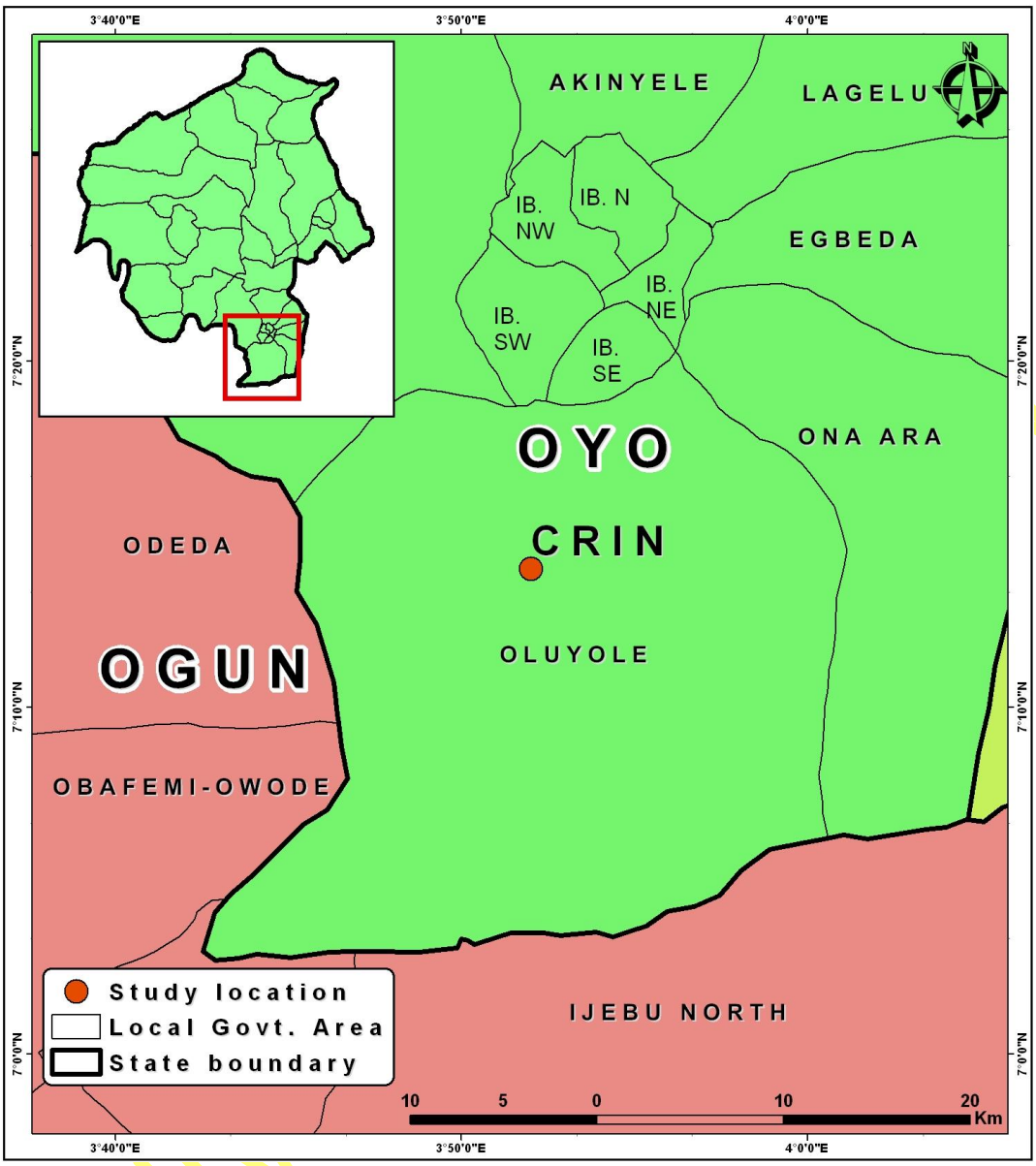


Fig 3.1a: **Map of Oyo State showing the location of Cocoa Research Institute of Nigeria (CRIN), Ibadan, Oluyole LGA**

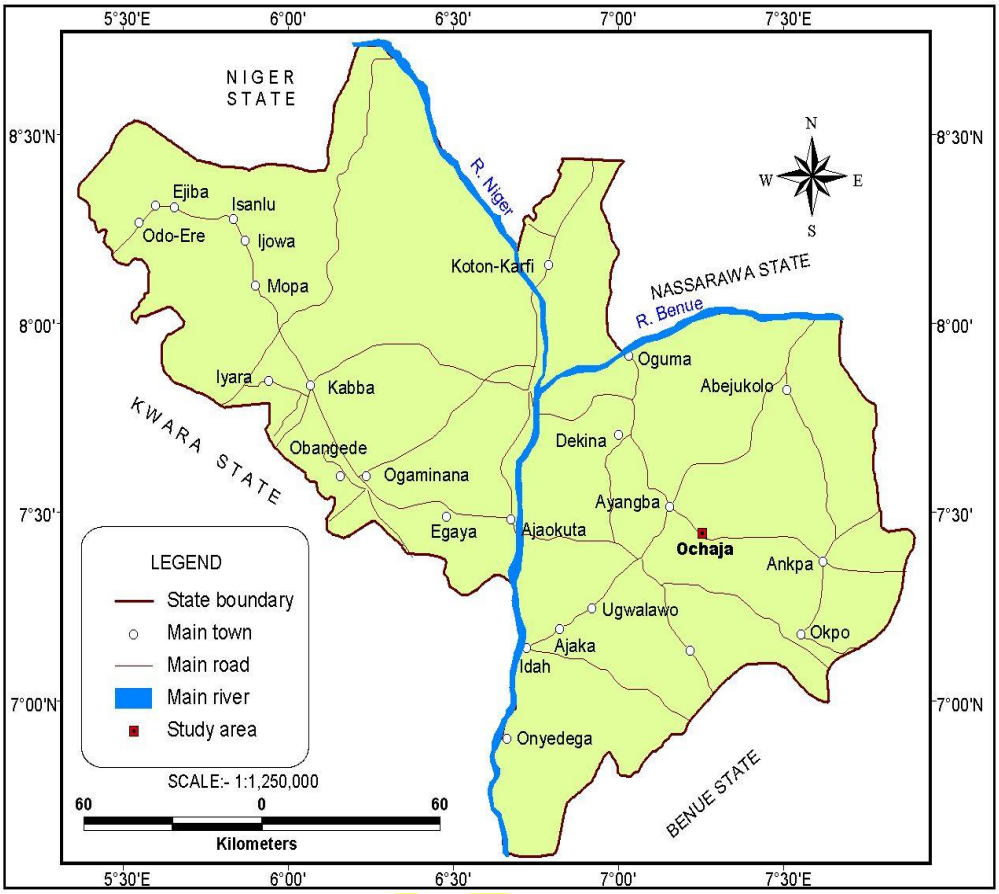
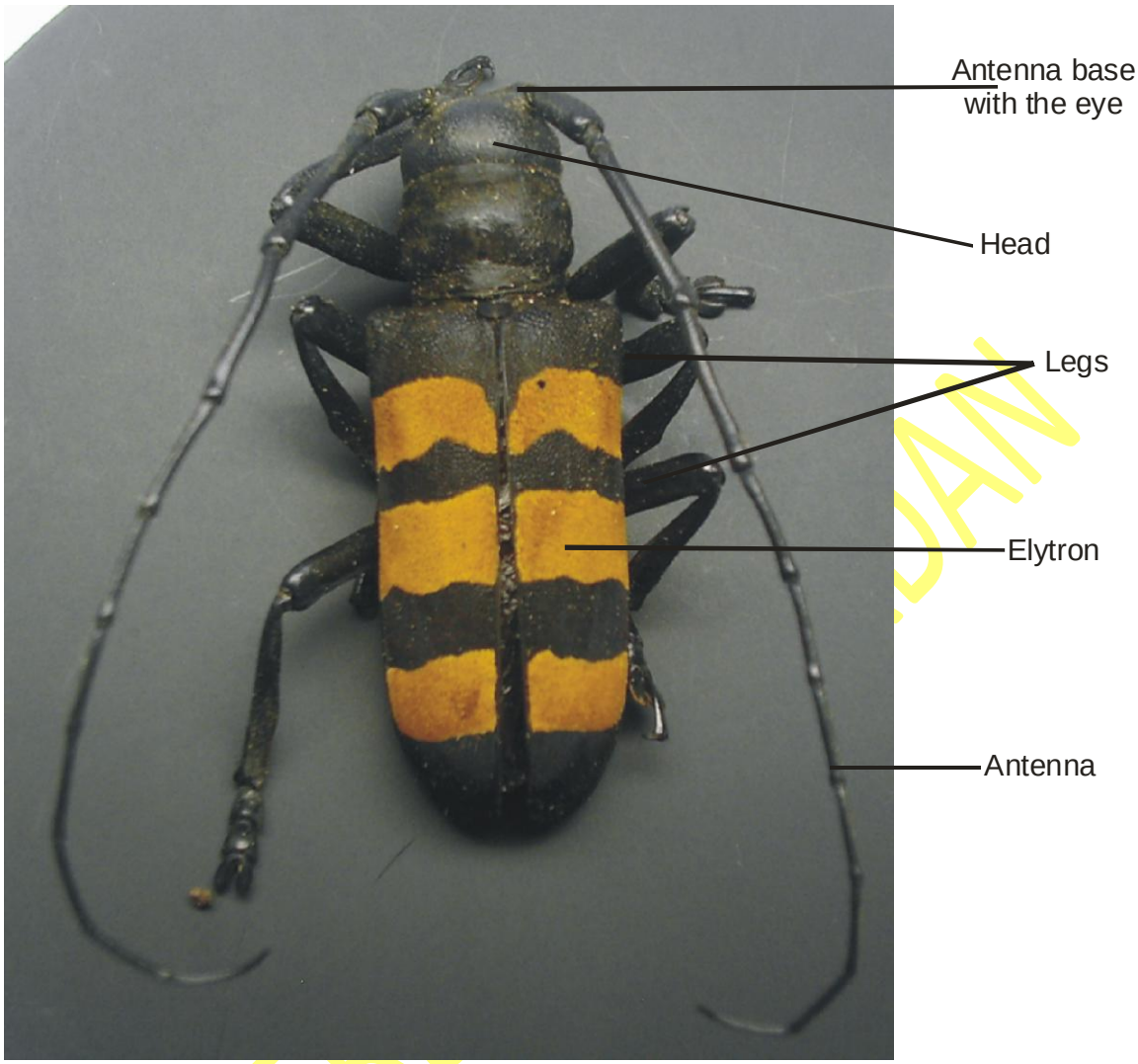


Fig 3.1b: Map of Kogi State showing the location of Cocoa Research Institute of Nigeria (CRIN) substation, Ochaja

3.1.3 Survey locations of *Analeptes trifasciata* spread in Nigeria

A survey of the spread of *A. trifasciata* (Plate 3.1) was carried out in Abia, Akwa Ibom, Anambra, Bayelsa, Benue, Cross-River, Delta, Ebonyi, Edo, Ekiti, Enugu, Federal Capital Territory (F.C.T), Imo, Kaduna, Kogi, Kwara, Lagos, Nasarawa, Niger, Ogun, Ondo, Osun, Oyo, Plateau, Rivers and Taraba States (Fig. 3.2). These States are all known to have natural environments that support the growth of cashew tree according to earlier Cashew Production Survey Reports in Nigeria (Ayodele *et al*., 2001; Topper *et al*., 2001; ADAN, 2002; Ezeagu, 2002; FAO, 2007; Hammed *et al*., 2007; Aliyu and Hammed, 2008; Asogwa *et al*., 2008).



Magnification: 2.6x

Plate 3.1: Dorsal view of *Analeptes trifasciata*

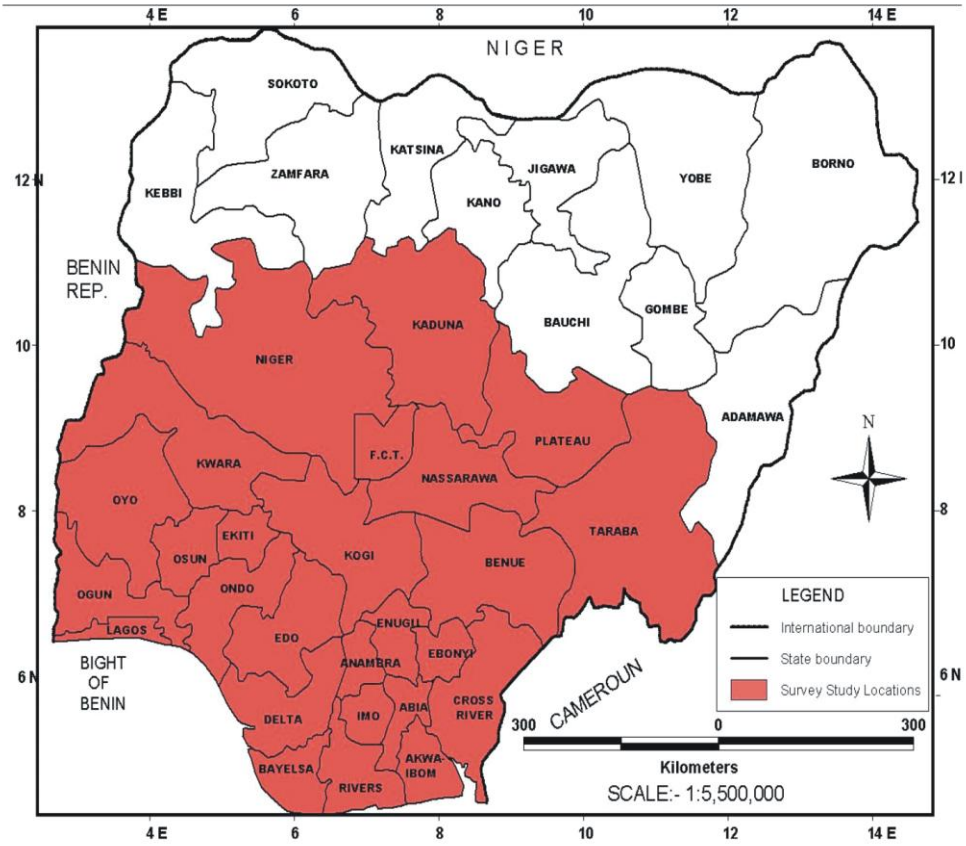


Fig 3.2: **Map of Nigeria showing the survey locations of *Analeptes trifasciata***

3.2 Survey of the geographical distribution of *Analeptes trifasciata*

A survey of the geographical spread of *A. trifasciata* was carried out in cashew plantations within the Federal Capital Territory and twenty five (25) States (Abia, Akwa-Ibom, Anambra, Bayelsa, Benue, Cross-River, Delta, Ebonyi, Edo, Ekiti, Enugu, Imo, Kaduna, Kogi, Kwara, Lagos, Nasarawa, Niger, Ogun, Ondo, Osun, Oyo, Plateau, Rivers and Taraba States) of Nigeria from July 2005 to June 2006. These States are all known to have natural environments that support the growth of cashew according to earlier Cashew Production Survey Reports in Nigeria (Ayodele *et al*., 2001; Topper *et al*., 2001; ADAN, 2002; Ezeagu, 2002; FAO, 2007; Hammed *et al*., 2007; Aliyu and Hammed, 2008; Asogwa *et al*., 2008). From each State, a random sample of 1000 cashew plants were selected from Government or Institutional farms as well as private farms and homesteads for assessment. The presence of *A. trifasciata* or their damage characteristics on the cashew trees such as girdled points on trees, girdled stems still hanging on the trees or fallen to the ground were used as the basis to establish their relative distribution in the different States.

3.3 Morphormetric characteristics of *Analeptes trifasciata*

External observations of the last abdominal portion of the insects in the field were used to collect and identify fifty adult males and females each of *A. trifasciata* for this study. The insects were gently killed in the Entomology Laboratory at CRIN headquarters, Onigambari, Ibadan by placing them in Kilner jars containing an absorbent cotton wool soaked in 95% ethyl acetate. Measurement of morphometric characteristics such as, body length, antennal length, head capsule length, head capsule width, thorax length, thorax width, abdominal length, abdominal width, last abdominal sternum width, elytra length, elytra width, membranous wing length and membranous wing length were taken with a pair of calipers or transparent ruler. The fresh body weight was also taken with an electronic weighing balance (Sartorius BP310S).

3.4 Monthly occurrence of *Analeptes trifasciata* infestation

Following the initial survey of the distribution of *A. trifasciata* in 25 States, two States (Oyo and Kogi) with high infestation rates of the pest were chosen for the study of

monthly occurrence of infestation. Three cashew plots (N7/3, SW3/2 and SS6), each serving as a replicate with 100 randomly selected plants were mapped out at the Cocoa Research Institute of Nigeria (CRIN) headquarters, Ibadan (Oyo State) to determine the monthly infestation of *A. trifasciata* in 2007. The same was replicated at Ochaja CRIN substation, Kogi State in cashew plots NW1, NW7 and SE5A. Infestation rates were recorded monthly by counting the number of trees with girdled points and girdled stems still hanging on them or fallen to the ground.

3.5 Field abundance of *Analeptes trifasciata*

The number of *A. trifasciata* found on the cashew trees was taken monthly for twelve months on 3 cashew plots (N7/3, SW3/2 and SS6) at CRIN headquarters and 3 plots (NW1, NW7, and SE5A) at Ochaja CRIN substation to determine the relative abundance of *A. trifasciata* in 2007. The insects were collected with the aid of a long pole, which was used to gently pull them down from the cashew treetop. They were picked up and placed inside an insect collection box (Plate 3.2), while those within hand height were picked up directly from the cashew stems. Sexes of the insects were observed and recorded.

3.6 Girdling damage characteristics of *Analeptes trifasciata* in the field

The activities of *A. trifasciata* were randomly observed in its natural habitat on all the selected cashew plots at CRIN headquarters, Ibadan and Ochaja CRIN substation for ten days. *Analeptes trifasciata* found on the trees were monitored daily at two (2) hours intervals between 7am to 6pm to ascertain the following: their mode of destruction, parts of cashew plant destroyed and the type of damage signs left behind by the insects. Photographs of the insect's activities were taken with zoom lens digital camera (Canon SD850 IS) for photo documentations.

***Analeptes trifasciata* on cashew tree top**

Plate 3.2: Removal of *Analeptes trifasciata* from cashew tree top with a long pole

3.7 Assessment of *Analeptes trifasciata* infestation within the cashew tree

The sudden snapping of girdled cashew stems, which falls to the ground or hangs on the tree, confirms an infestation of a cashew plant by *A. trifasciata*. The cashew trees in the three selected cashew plots, each at CRIN headquarters, Ibadan and Ochaja CRIN substation were closely monitored to determine the distribution of *A. trifasciata* infestation on parts of the cashew tree. The experimental design was a Randomized Complete Block Design with three replications in each location. The number of cashew trees girdled branches that have snapped and fallen to the ground and those still hanging on the tree canopy were recorded monthly (Plate 3.3a and b). Also the number of snapped or cut vertical and horizontal stem stalks left behind on each tree was recorded every month to determine the preferred growth position of girdled stems by *A. trifasciata* (Plate 3.3c and d). The data collected was subjected to a t-test for any significant difference between the branches that have fallen to the ground and those still hanging on the tree and also between the number of snapped vertical and horizontal stem stalks.

3.8 Determination of the preferred height of girdling by *Analeptes trifasciata*

The preferred height of girdling by *A. trifasciata* was measured on random samples of infested cashew trees within the three selected plots, each, at CRIN headquarters, Ibadan and Ochaja CRIN Substation, with an aid of a measuring pole and ladder. The experimental design was a Randomized Complete Block Design with three replications in each location. A total of 150 randomly selected cashew trees stands were assessed, 25 in each of the 6 experimental plots (3 plots at Ibadan and 3 plots at Ochaja). Two girdled positions were randomly sampled in each of the selected tree, giving a total

Girdled portion

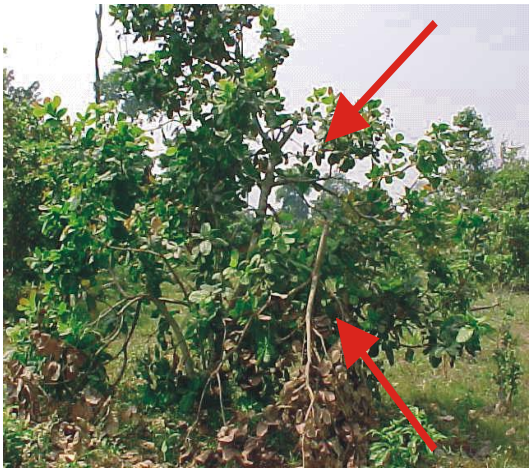


Plate 3.3a: A girdled cashew branch already fallen to the ground.

Girdled portion

Plate 3.3c: A horizontal girdled cashew branch

Hanging cashew girdled branch

Plate 3.3b: A girdled cashew branch still hanging on the treetop.

Girdled portion

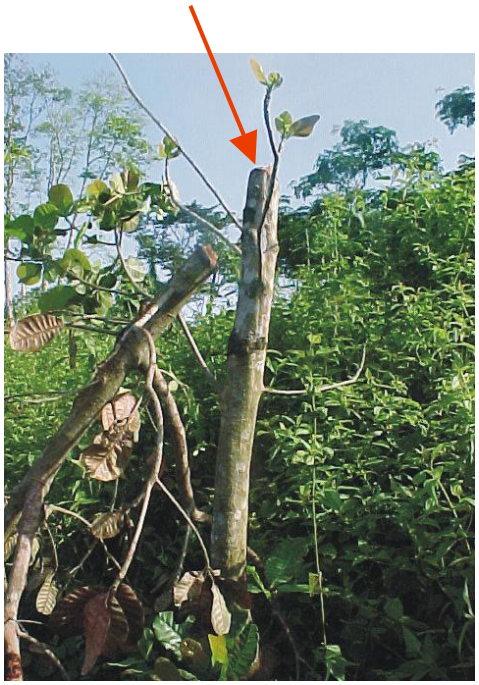


Plate 3.3d: A vertical girdled cashew branch.

sample size of 300. The measuring pole, which was calibrated in meters, was placed directly on the ground below the girdled stem stalk and with the help of the ladder the point corresponding to the girdled point on the pole was marked and recorded. The ladder was used for girdled positions high up on the cashew trees, while lower girdled stalks within hand height were assessed standing. The frequency distribution of the preferred height of girdled cashew branches by *A. trifasciata* was computed and plotted.

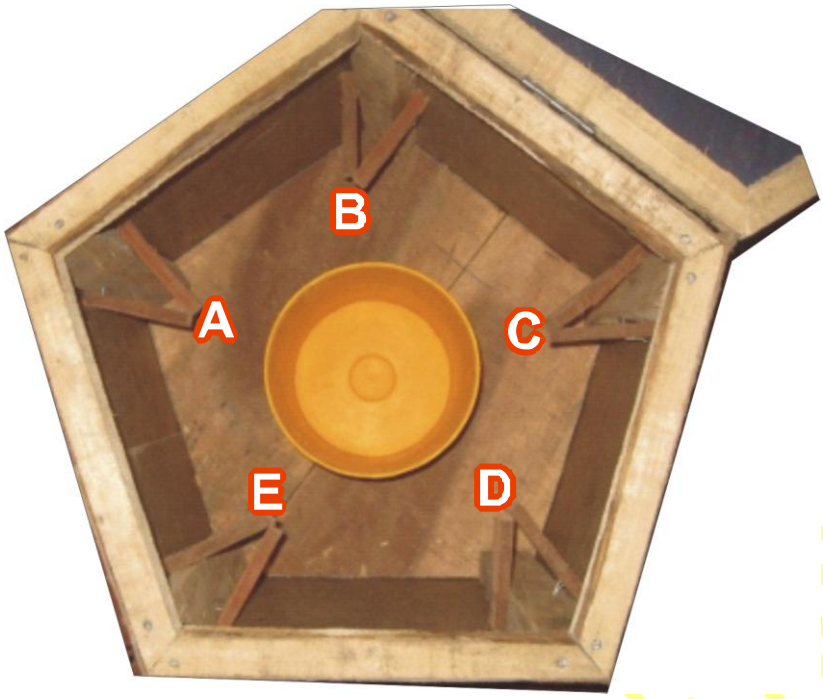
3.9 Determination of the diameter of girdled cashew branches

A total of three hundred (300) girdled cashew branches were used for this assessment. Fifty (50) girdled branches each were randomly collected from the six cashew experimental plots (3 plots at Ibadan and 3 plots at Ochaja). The stems were measured at the base with a pair of calipers to determine the diameter of preferred girdled stems by *Analeptes trifasciata*. The experimental design of the plots from where the girdled branches were collected was a Randomized Complete Block Design with three replications in each location. The frequency distribution of the diameter of preferred girdled branches by *A. trifasciata* was computed and plotted.

3.10 Preference of cashew plant parts for infestation by *Analeptes trifasciata*

Different parts of the cashew plant (stem, leaves, flowers, pseudo apple and nuts) were used for this study in the laboratory to identify the food source of adult *A. trifasciata*. The cashew plant parts were placed at different corners of a pentagonal feeding preference chamber (Plate 3.4) at equal distance of 30cm from each other, before introducing adult males and females of *A. trifasciata* (50 each) into the central cup of the

cage. The insects were collected from the field a day prior to the experimental date and starved for 24 hours before their introduction into the experimental cages. The experimental design was a Completely Randomized Design (CRD) with three replications. The number of insects found on each plant part was recorded at two hours intervals for 24 hours. The data was subjected to analysis of variance (ANOVA) to determine preference of the adults to the cashew plant parts.



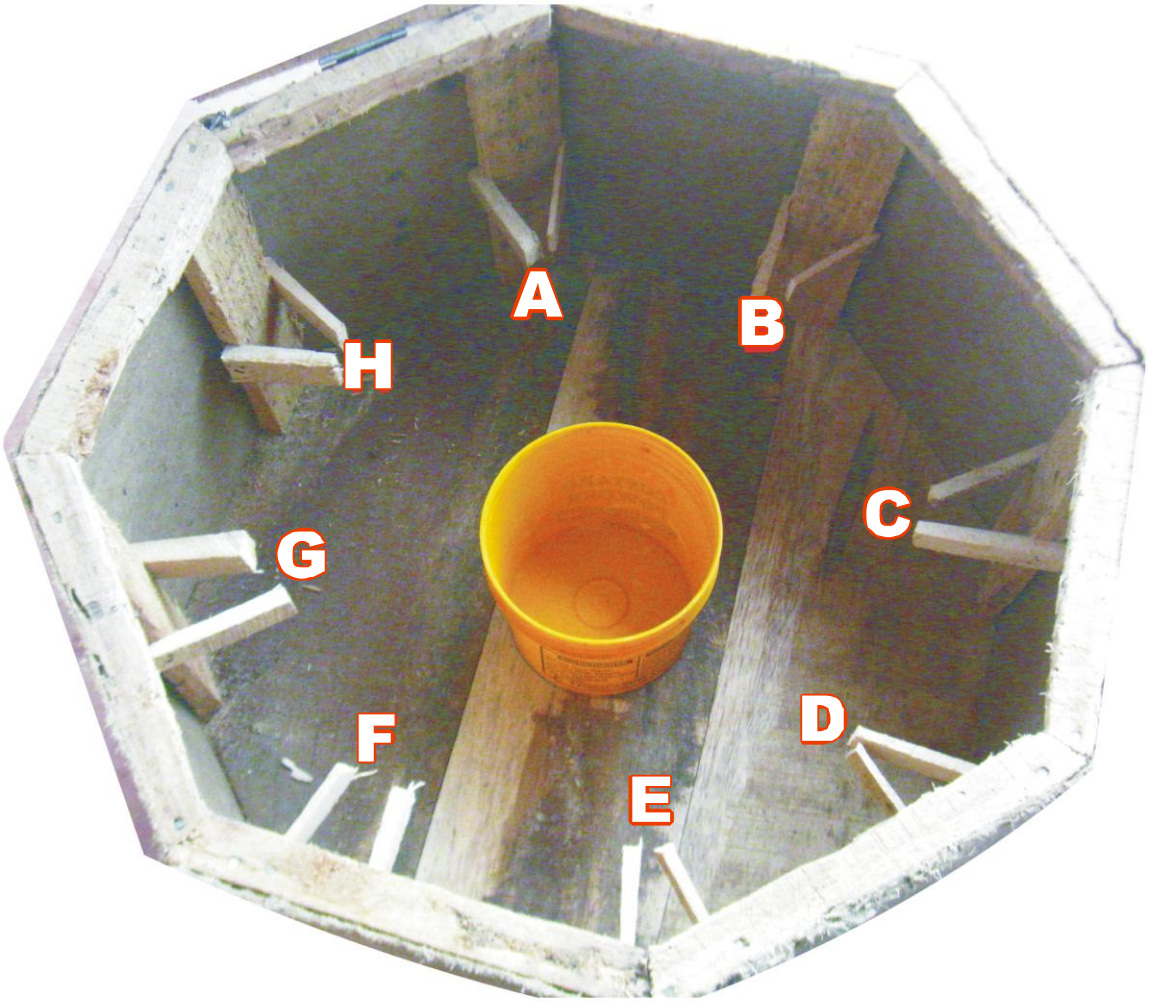
Magnification: 2.6x

KEY: A -- Stem,
B -- Leaves
C - Nuts
D – Pseudo—apple
E -- Flowers

Plate 3.4: A pentagonal feeding preference chamber showing the various points for the placement of different parts of cashew plants

3.11 Assessment of attractiveness of various alternate host plants stems to *Analeptes trifasciata*

The food preference of *A. trifasciata* was investigated using stems of cashew and seven identified alternate host plants (*Lannea welwitschil, Spondias mombin, Terminalia catappa, Theobroma cacao, Eucalyptus spp, Ricinodendron heudelotii* and *Manihot esculenta*). The stems (50cm each) were placed at different corners of an octagonal feeding preference chamber (Plate 3.5) at equal distance of 30cm from one another before introducing 80 adult males and 80 adult females of *A. trifasciata* into the central cup of the chamber. The insects were collected from the field and starved for 24 hours before this exercise. The experimental design was a Completely Randomized Design (CRD) with three replications. Records were taken on the number of *A. trifasciata* found on each food source at two hours intervals for 24 hours. The data was subjected to Analysis of variance (ANOVA) to determine any significant difference in food preference of the insect pest.



Magnification: **2.6x**

KEY: A – *Lannea welwitschil*
B – *Spondias mombin*
C – *Terminalia catappa*
D – *Theobroma cacao*
E – *Eucalyptus spp*
F – *Ricinodendron heudelotii*
G – *Manihot esculenta*
H –*Anacardium occidentale*

Plate 3.5: **An octagonal feeding preference chamber showing the various points for the placement of the alternate host plants stems**

CHAPTER 4
RESULTS

4:2 Geographical distribution of *Analeptes trifasciata* in Nigeria

The result of the survey (Table 4.1) showed outstanding levels of devastation of the cashew farms by *A. trifasciata* in most States surveyed. The highest infestation rate of 82.6% was recorded at Kogi State, which was closely followed by Oyo (79.3%), Abia (62.4%), Imo (61.3%), Osun (61%) and Anambra (59.3%). The insect were not found in Akwa-Ibom, Bayelsa and Rivers States. A very low rate of infestation was recorded for Plateau (5.6%), FCT (8%), Niger (12.5%), Taraba (12.7%), Kaduna (13%) and Enugu (13.7%). Figure 4.1 is a map of Nigeria showing the geographical distribution and abundance of *A. trifasciata*. There was a high infestation of *A. trifasciata* in Oyo, Kwara, Osun, Ekiti, Ogun, Ondo, Edo, Kogi, Lagos, Benue, Anambra, Imo and Abia states (red parchments, indicating infestation rate of 35% and above). The beetles were not found in Akwa-Ibom, Bayelsa and Rivers States (green parchments). However, there was a moderate to low infestation in Niger, Kaduna, FCT, Nassarawa, Plateau, Taraba, Enugu, Ebonyi, Cross-River and Delta states (blue parchments, ie infestation rate of between 2 to 34%). The white parchments (Sokoto, Kkebbi, Zamfara, Katsina, Kkano, Jigawa, Bauchi, yobe, Gombe, Adamawa and Bornu) are not known cashew growing areas in Nigeria.

Table 4.1: Field infestation of cashew by *Analeptes trifasciata* in Nigeria

States		Number of trees infested	% Infestation.
1.	Abia	624	62.4
2.	Akwa-Ibom	0	0
3.	Anambra	593	59.3
4.	Bayelsa	0	0
5.	Benue	427	42.7
6.	Cross-River	233	23.3
7.	Delta	325	32.5
8.	Ebonyi	215	21.5
9.	Edo	505	50.5
10.	Ekiti	578	57.8
11.	Enugu	137	13.7
12.	F.C.T	80	8
13.	Imo	613	61.3
14.	Kaduna	130	13
15.	Kogi	826	82.6
16.	Kwara	437	43.7
17.	Lagos	479	47.9
18.	Nasarawa	251	25.1
19.	Niger	125	12.5
20.	Ogun	538	53.8
21.	Ondo	512	51.2
22.	Osun	610	61
23.	Oyo	793	79.3
24.	Plateau	56	5.6
25.	Rivers	0	0
26.	Taraba	127	12.7

Key: n = 1000 trees

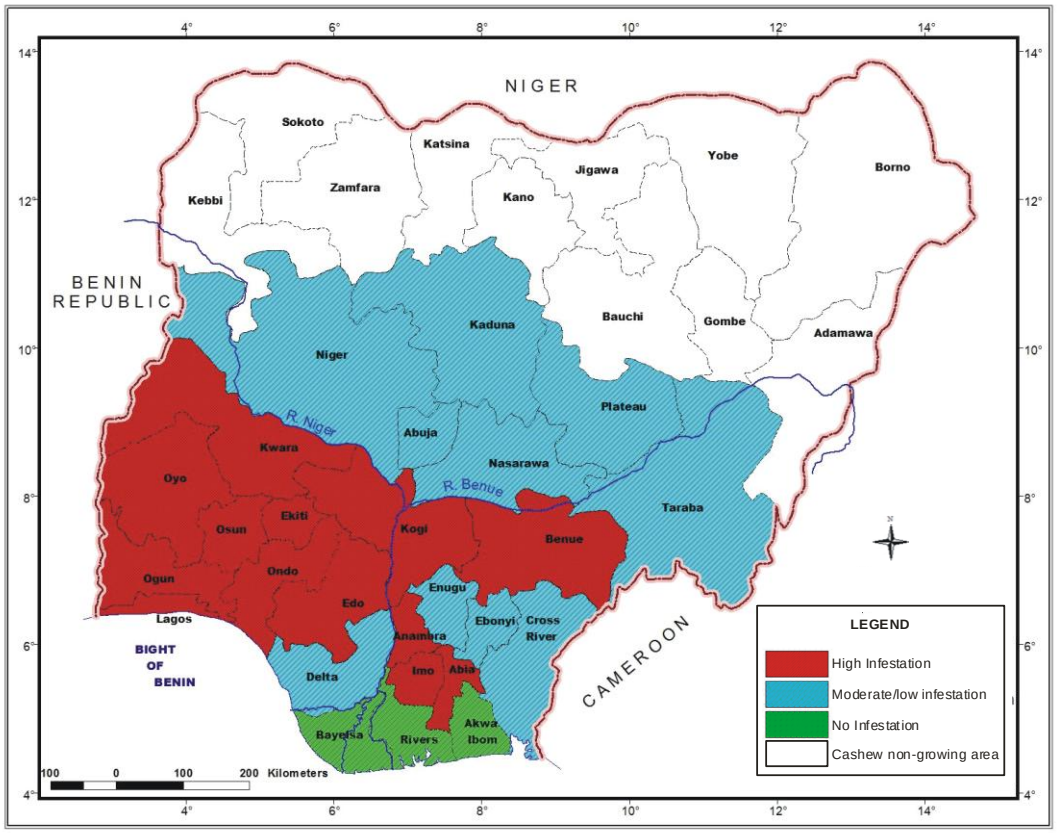


Fig 4.1: **Map of Nigeria showing the distribution and abundance of *Analeptes trifasciata* in Nigeria**

4.3 Morphometric characteristics of *Analeptes trifasciata*

The mean body morphometric measurements (± SE) of adult *A. trifasciata* obtained are shown in Table 4.2 These characteristics were reliably used to differentiate the sexes of the insects. The adult *A. trifasciata* is a large beetle, 4.0 ± 0.1 cm long and 1.0 ± 0 cm (male) to 1.1 ± 0 cm (females) wide at the base of the thorax. The head, thorax, antennae and legs of the beetles are black. The elytra have three broad orange transverse bands separated by two black bands of irregular shape (Plate 1). The fresh body weight of females (3.0 ± 0.1 g) differed significantly ($p< 0.05$) from the males (2.7 ± 0.1 g). The width of the head capsule of the females (0.8 ± 0 cm) were significantly different ($p< 0.05$) from those of the males (0.7 ± 0 cm), however, both sexes had same length of head capsule measuring 0.5 ± 0 cm). The females possess longer abdomen (1.9 ± 0 cm), which were significantly ($p< 0.05$) longer than those of the males (1.7 ± 0 cm). However, the width of the abdomen of the males (1.0 ± 0 cm) was not different from those of females (1.1 ± 0 cm). The females length of elytra (3.1 ± 0 cm) was significantly ($p< 0.05$) longer than 2.9 ± 0 cm recorded for the males, while the width of last abdominal sternum of the males (0.7 ± 0 cm) were shorter than those of the females (3.0 ± 0.1 cm). Other morphometric parameters were found to overlap considerably between the males and females (Table 4). For instance, the length and width of the thorax were similar in both males (1.0 ± 0 cm) and females (1.1 ± 0 cm) respectively. Also the body length of both males (4.0 ± 0.1 cm) and the females (4.0 ± 0 cm) showed no difference. The width of elytra (Males: 1.2 ± 0.1 cm; Females: 1.2 ± 0.1 cm), length of membranous wings (Males: 3.2 ± 0.1 cm; Females: 3.2 ± 0 cm) and width of membranous wings (Males: 1.2 ± 0 cm; Females: 1.2 ± 0 cm) all followed the same pattern with no significant differences.

In addition to the morphometric characteristics, an external observation of the ventral view of the insect shows five visible abdominal segments, which are readily recognized in both sexes. However, on careful observation, a mid ventral structure can be seen on the last abdominal sternum of the females, which is absent in the males (Plate 4.1a, 4.1b). This structural contrast, which was still observed after dissecting the adults, is used as a satisfactory criterion for separating the sexes. The ovipositor of the females was embedded below this structure.

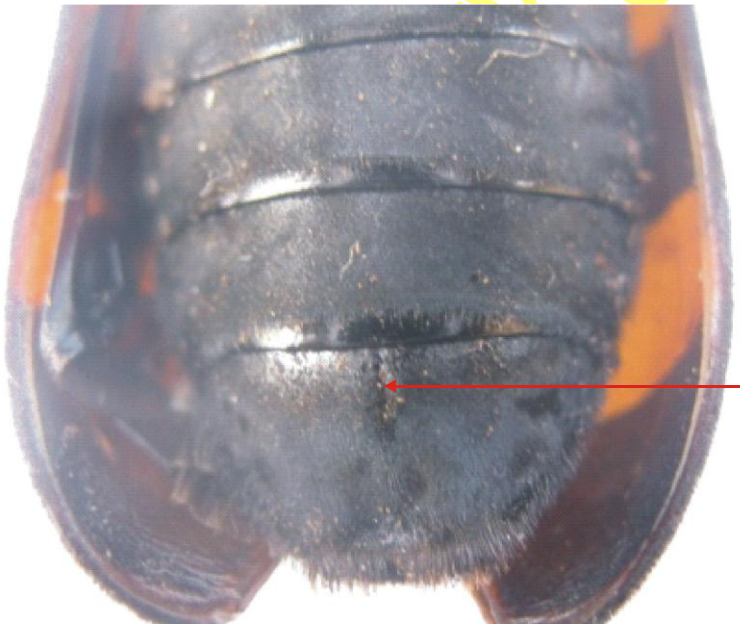
Table 4.2: Mean body morphometric measurements (± SE) of adult male and female *Analeptes trifasciata*

Parameters	Adult morphometrics (cm) (n = 50) Male	Female
Length of antennae (cm)	6.0 ± 01**	5.3 ± 0
Length of head capsule (cm)	0.5 ± 0	0.5 ± 0 ns
Width of head capsule (cm)	0.7 ± 0	0.8 ± 0**
Length of abdomen (cm)	1.7 ± 0	1.9 ± 0**
Width of abdomen (cm)	1.0 ± 0	1.1 ± 0 ns
Length of thorax (cm)	1.0 ± 0	1.1 ± 0 ns
Width of thorax (cm)	1.0 ± 0	1.1 ± 0 ns
Length of body (cm)	4.0 ± 0.1	4.0 ± 0 ns
Length of elytra (cm)	2.9 ± 0	3.1 ± 0**
Width of elytra (cm)	1.2 ± 0.1	1.2 ± 0.1ns
Length of membraneous wing (cm)	3.2 ± 0.1	3.2 ± 0.1ns
Width of membraneous wing (cm)	1.2 ± 0	1.2 ± 0.0ns
Width of last abdominal sternum (cm)	0.7 ± 0	0.8 ± 0**
Fresh body weight (g)	2.7 ± 0.1	3.0 ± 0.1**

** - Significant at p = 0.05
ns - No significant difference

Magnification: 2.6x

Plate 4.1a: Ventral view of adult male *Analeptes trifasciata* with no mid ventral slit at the last abdominal sternum



Magnification: 2.6x

Plate 4.1b: Ventral view of adult female *Analeptes trifasciata* with the last abdominal sternum showing a mid ventral slit

4:4. *Analeptes trifasciata* infestation

There was declining trend of the pest infestation from January to March, with no occurrence in April to August. An increased infestation of the pest followed from September to December (Fig 4.2). The number of *A. trifasciata* girdled branches collected at Ochaja plots (535.8 ± 27.6) differed significantly ($P < 0.05$) from that of Ibadan plots (323.7 ± 18.4) (Table 4.3). The cashew trees at Ochaja experimental plots were totally infested (100%) by *A. trifasciata* within the experimental period. However, an infestation rate of 84.3% was recorded at Ibadan plots, which was not significantly different from that of Ochaja plots.

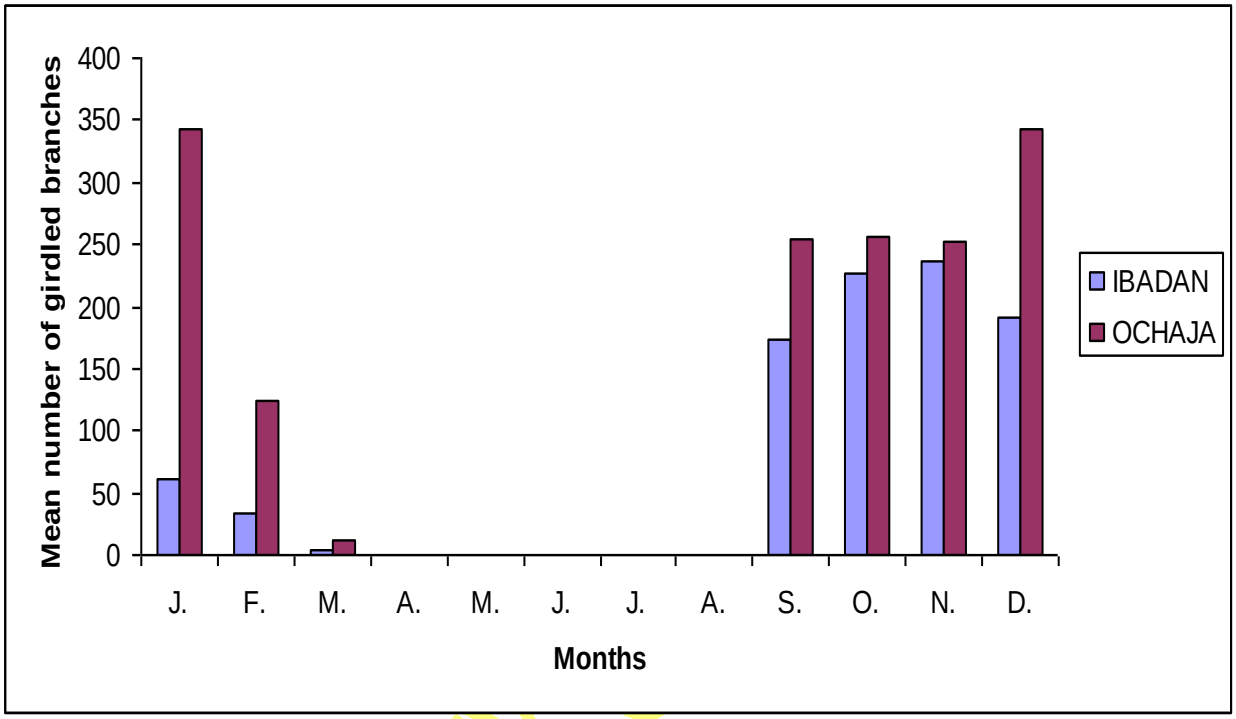


Fig 4.2: **Number of girdled branches collected from cashew plots at Ibadan and Ochaja**

Table 4.3: The incidence of *Analeptes trifasciata* infestation on cashew plots

Locations*	Total no of girdled branches	Mean no of infested trees	%Infestation
Ibadan	323.7±18.4	84.3±5.5	84.3%
Ochaja	535.8±27.6	100±0.0	100%
	**	***ns***	***ns***

*Each location value represents a mean of 3 replicate plots of 100 cashew stands each.
** - Significant at p= 0.05
ns - No significant difference

4:5. Abundance of *Analeptes trifasciata*

A declining trend of the pest population from January to March, with little occurrence in June was observed at both Ibadan and Ochaja cashew plots. This was followed by an increased population of the pest from September to December. Peak of infestation (117 - 130 *Analeptes*) per plot was recorded from September to December, and least (7 *Analeptes*) in June (Fig 4.3). The population of the pest was relatively higher at Ibadan cashew plots (554.3 ± 41.3) compared to Ochaja plots (360.7 ± 42.4). The mean monthly population count of *A. trifasciata* at Ibadan (276.7±5.0 males and 277.7±15.6 females) and Ochaja (179.7±11.1 males and 181.0±10.2 females) cashew plots showed no significant difference between the number of males and females collected (Table 4.4). The insects were always found in pairs in all the plots, but when disturbed, they hide or fly away from the source of disturbance.

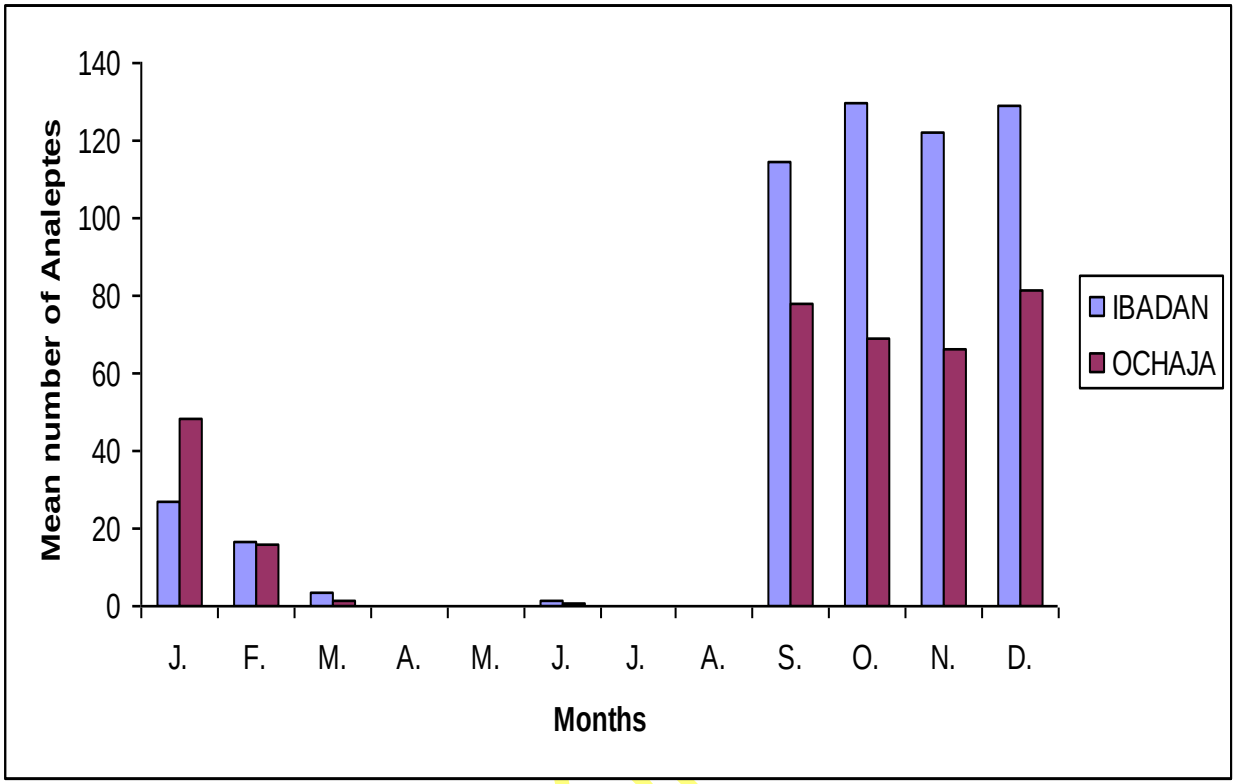


Fig 4.3: **Monthly distribution of *Analeptes trifasciata* on cashew plots at Ibadan and Ochaja**

Table 4.4: Number of *Analeptes trifasciata* collected from the various cashew plots

Locations*	Total no of insects	No of males	No of females	
Ibadan	554.3 ± 41.3	276.7±5.0	277.7±15.6	***ns***
Ochaja	360.7 ± 42.4	179.7±11.1	181.0±10.2	***ns***
	**	**	**	

*Each location value represents a mean of 3 replicate plots of 100 cashew stands each.
** - Significant at p = 0.05
ns - No significant difference

4:6 Girdling damage characteristics of *Analeptes trifasciata* in the field

The girdling of cashew branches by *A. trifasciata* results in drying out of the stems from the point of girdling (Plate 4.2a). Some of the girdled stems snap and either fall to the ground or hang on cashew tree tops (Plates 3.3a and 3.3b). Stumps of affected branches usually regenerate and produce many side shoots, giving an untidy appearance (Plate 4.2b). In some cases, the girdled cashew branch recovers by producing a lot of gum exudates around the girdled portion, followed by an outgrowth to heal the wound (Plate 4.2c). *Analeptes trifasciata* feed by scraping the bark of the cashew stems (Plate 4.2d) and usually mate and lay their eggs below the bark above the girdled portion of the cashew branch that will hang or fall to the ground (Plate 4.2e). The beetles were not seen girdling other cashew parts (leaves, flowers, fruits and nuts) in the field.

Girdled portion

Plate 4.2a

Healed girdled portion

Plate 4.2c

Plate 4.2b

Key:

Plate 4.2a: The cashew stem girdler (*Analeptes trifasciata*) and its damage pattern

Plate 4.2b: Regenerated stump of girdled cashew branch by *Analeptes trifasciata* with many side shoots

Plate 4.2c: A girdled cashew branch recovering from girdling effects of *Analeptes trifasciata*.

Plate 4.2d: Scraping of bark of cashew branch, characteristics feeding sign of *Analeptes trifasciata*

Plate 4.2e: Mating of *Analeptes trifasciata* after feeding and girdling of cashew branch

4:7 Assessment of *Analeptes trifasciata* infestation within the cashew tree

The mean number of girdled stem still hanging on top of the tree canopies at Ibadan (273.3±14.9) significantly differed ($p < 0.05$) from those fallen to the ground (212.0±17.9) (Table 4.5). However, at Ochaja plots a mean number of 413.7±62.9 hanging branches and 390.0±11.8 fallen branches were recorded, which showed no significant difference. A higher mean number of girdled branches (803.7±41.3) were recorded at Ochaja plots when compared with 485.3±25.2 at Ibadan plots, which was highly significant. However, at Ibadan cashew plots the mean number of girdled vertical branches (243.3±20.2) did not differ significantly from the girdled horizontal branches (243.0±6.5). Also, at Ochaja plots the girdled vertical branches (386.7±13.9) showed no significant difference from the girdled horizontal branches (417.0±22.3) (Table 4.6).

Table 4.5: Spatial distribution of *Analeptes trifasciata* infestation on cashew trees

Location (plots)*	Total girdled branches	No of hanging branches	% Hanging branches	No of fallen branches	% Fallen branches
Ibadan	485.3±25.2	273.3±14.9	56.4	212.0±17.9**	43.6
Ochaja	803.7±41.3 **	413.7±62.9 **	52.3 *ns*	390.0±11.8 **	48.7 *ns*

*Each location value represents a mean of 3 replicate plots of 100 cashew stands each.
** - Significant at p = 0.05
ns - No significant difference

Table 4.6: Preferred cashew stem position for girdling by *Analeptes trifasciata*

Locations (plots)*	Total girdled branches	Girdled vertical branches no	%Girdled vertical branches	Girdled horizontal branches no	% Horizontal branches
Ibadan	485.3±25.2	243.3±20.2	49.6	243.0±6.5 ***ns***	50.4
Ochaja	803.7±41.3 **	386.7±13.9 **	48.1 ***ns***	417.0±22.3 **	51.9 ***ns***

*Each location value represents a mean of 3 replicate plots of 100 cashew stands each.
** - Significant at p = 0.05
ns - No significant difference

4:8 Height of girdling by *Analeptes trifasciata*

Figure 4.4 shows the frequency distribution of preferred height range of girdled cashew stem by *A. trifasciata.* The pest was found to prefer medium to moderately tall trees within the range of 2m to 4.99m heights, as they did not attack the very low and tall trees.

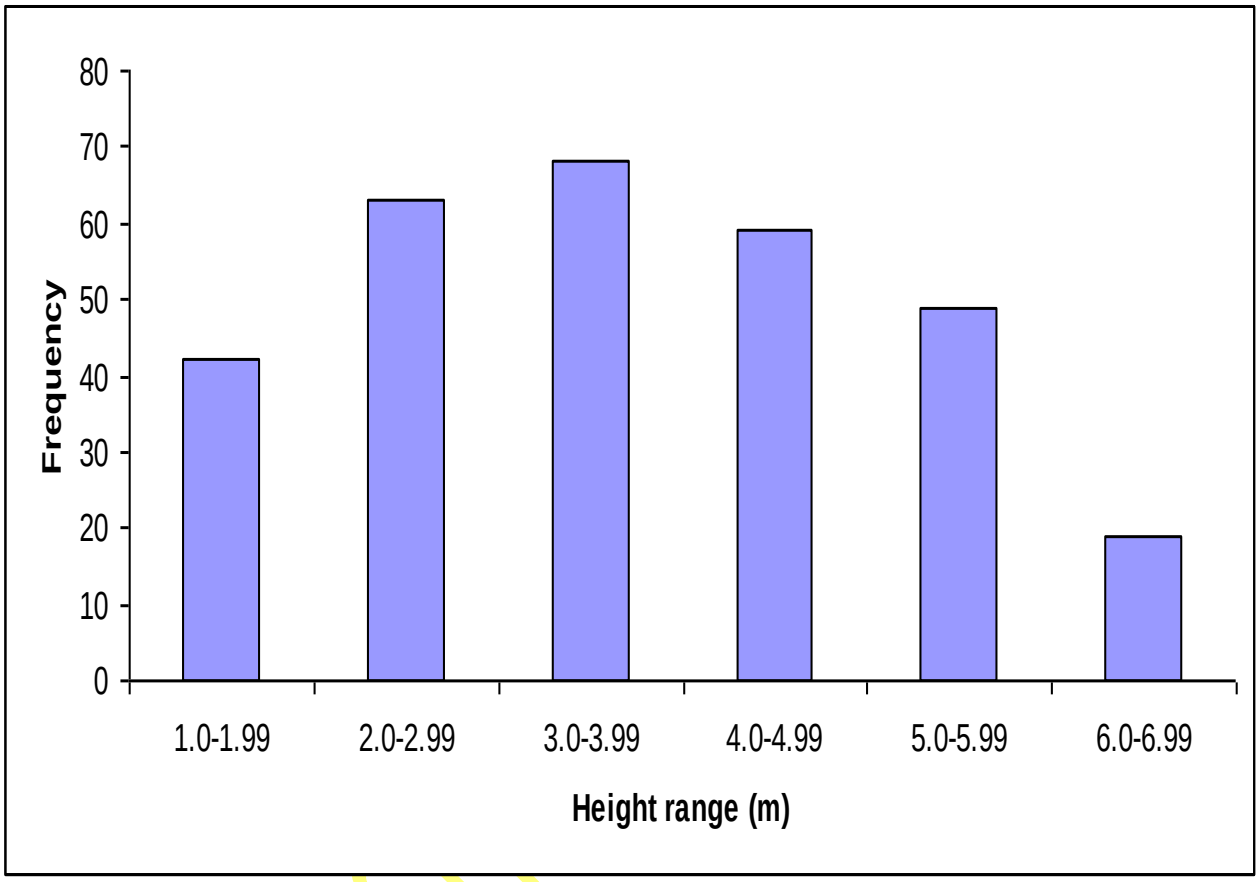


Fig. 4.4: Frequency distribution of preferred height range (m) of girdled cashew stem by *Analeptes trifasciata* from ground level.

4:9 Diameters of girdled cashew branches

The frequency distribution of the preferred diameter range of girdled cashew branches by *A. trifasciata* is shown in Fig 4.5. The insect girdled medium sized cashew branches within the ranges of 3.0cm to 6.99cm. However, over 50% of the girdled stems were within the diameter range of 4.0cm to 5.99cm. The insect did not girdle the big cashew trunks and very small ones.

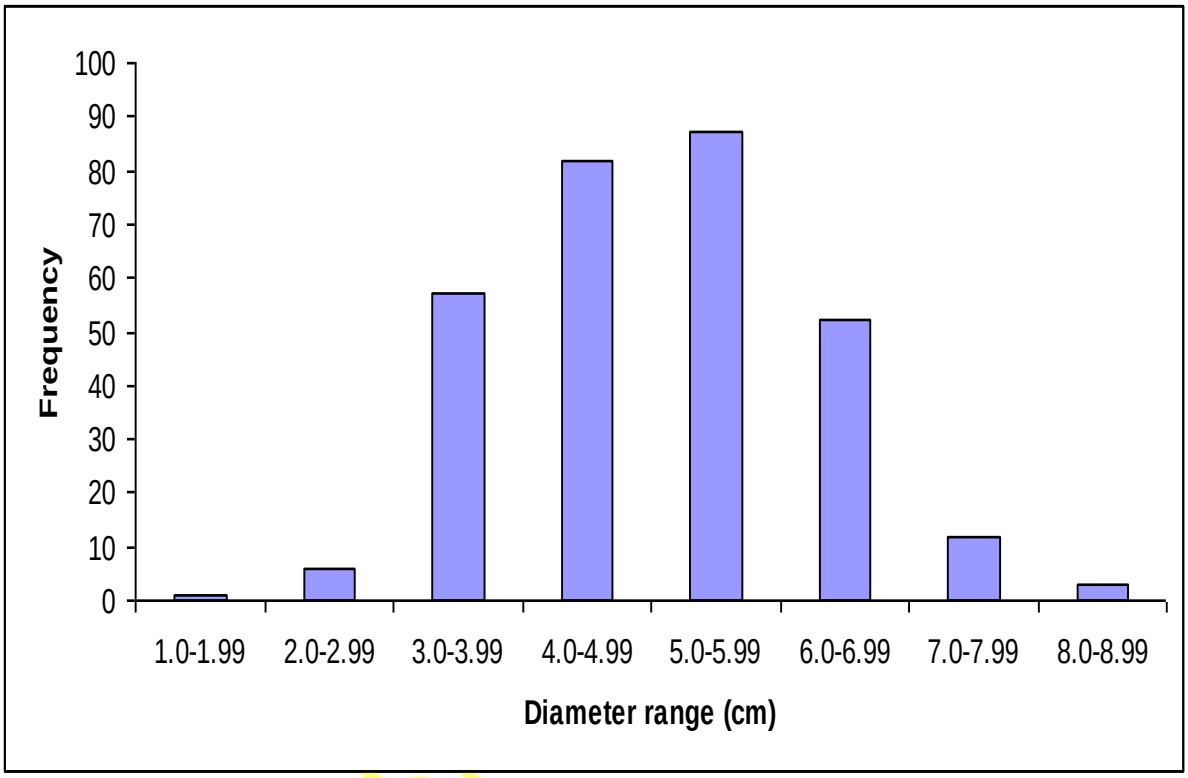


Fig. 4.5: Frequency distribution of preferred diameter range (cm) of girdled cashew branches by *Analeptes trifasciata*.

4:10 Preference of cashew plant parts for infestation by *Analeptes trifasciata*

The mean number of *A. trifasciata* found on each food source (cashew stems, leaves, nuts, flowers and psudo-apple) every two hours in the food preference chamber is shown in Table 4.7. A very significant ($P < 0.05$) number of the beetles (73 to 92.7) consistently fed on the cashew stems for the whole 24 hours experimental period (EP), which differed significantly ($P < 0.05$) from those found on all the other food sources (0 to 2.3). No feeding signs were observed on the leaves, flowers, fruits and nuts after the 24 hours EP.

Table 4.7: Attractiveness of parts of major host plant (cashew) to *Analeptes trifasciata*

	Exposure periods (hours)											
	2	4	6	8	10	12	14	16	18	20	22	24
Plant parts.	Mean number of *A. trifasciata* found on each food source*											
Stems	88[a]	92.3[a]	91[a]	92.7[a]	92[a]	88.7[a]	81.3[a]	75[a]	78.3[a]	81.3[a]	75.7[a]	73[a]**
Leaves	2.3[b]	1.7[b]	1.7[b]	1.3[b]	1[b]	0.3[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
Flowers	5[b]	1.7[b]	2.3[b]	1.7[b]	1[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
Fruit	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]
Nuts	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]	0[b]

*Each value represents mean of three replicates.
**Means with the same superscript in the same column are not significantly different (P > 0.05) by Tukey's test

4:11 Attractiveness of various alternate host plants stems to *Analeptes trifasciata*

A large number of the beetles were found feeding consistently on *Anarcardium occidentale*, *Spondias mombin*, *Lannea welwitschil*, *Terminalia catappa*, *Eucalyptus* spp and *Ricinodendron heudelotii* stems throughout the experimental period (EP) (Table 4.8). However, *A. occidentale* and *S. mombin* had the highest number of beetles (18 to 38.7) found feeding on them, which differed significantly ($P < 0.05$) from those found on all the other host plant food sources. This was closely followed by *L. welwitschil*, which had 15 to 28.3 beetles feeding on it at various time intervals. *Theobroma cacao* and *M. esculenta* had the lowest number of the beetles (4 to 10) found on them.

Table 4.8: Attractiveness of various alternate host plant stems to *Analeptes trifasciata*

	Exposure periods (hours)											
	2	4	6	8	10	12	14	16	18	20	22	24
Plant parts.	Mean number of *A. trifasciata* found on each food source*											
A. occidentale	26.3[a]	26.3[a]	32.7[a]	29[a]	23.3[a]	23.3[a]	29.3[a]	25.7[a]	31[a]	37.7[a]	38.7[a]	37[a]**
L. welwitschil	27.7[b]	28.3[b]	26[b]	22.3[b]	15.3[b]	18.3[b]	24.3[b]	17.7[b]	15.7[b]	19[b]	15[b]	10.7[b]
S. mombin	25.3[a]	18[a]	25[a]	23[a]	32.3[a]	33.3[a]	26.7[a]	31.3[a]	27.3[a]	31.7[a]	32.7[a]	31[a]
T. catappa	19.7[c]	19[c]	16.7[c]	24[c]	17.3[c]	17.6[c]	12[c]	11.7[c]	14.7[c]	15.3[c]	11.3[c]	14[c]
T. cacao	8[d]	8.3[d]	7.3[d]	4.6[d]	3.6[d]	6[d]	4[d]	3.3[d]	5.3[d]	3.6[d]	5.3[d]	4[d]
Eucalyptus	21[c]	22[c]	16.7[c]	19.3[c]	13.7[c]	11.3[c]	7.7[c]	5.3[c]	6[c]	8.3[c]	8.7[c]	10.7[c]
R. heudelotii	17[c]	20.7[c]	21[c]	23[c]	11[c]	11[c]	12[c]	13.7[c]	14.3[c]	13[c]	15[c]	14.3[c]
M. esculenta	10[d]	9.7[d]	9[d]	10.3[d]	8.6[d]	7.3[d]	5[d]	6[d]	5[d]	4[d]	4.3[d]	4.3[d]

*Each value represents mean of three replicates.
**Means with the same superscript in the same column are not significantly different (P > 0.05) by Tukey's test

CHAPTER 5

DISCUSSION

This study has revealed that the cashew stem girdler, *Analeptes trifasciata* is a major pest of cashew in Nigeria, which is in line with earlier reports by Omole, 1977a; Igboekwe, 1982; 1983; 1984; 1985). It is a low-density pest that is found in pairs (i.e. males and females are always together). The adult *A. trifasciata* is a typical "Longicorn" beetle with attractive colour. The fully developed adult beetle has an average body length of 3.96cm and its antennal length is longer than the body. The head, prothorax, legs and antennae are black. The elytra have three orange coloured, broad transverse bands separated by two black bands of irregular shape. The base and ends of their elytra are black.

The relatively high population of the beetles noted at Ibadan cashew experimental plots could be attributed to differences in environmental factors (vegetation, rainfall, temperature and relative humidity) between Ochaja plots and Ibadan plots. The location of Ibadan is a typical marginal rainforest region that supports a wide range of alternate host trees of *A. trifasciata*. Most of these host trees were not found at Ochaja. The high number of girdled branches in January at Ochaja was fallout from the previous year's infestation of the plots. Cultural control programme for the pest was not in place at the plots unlike the Ibadan plots prior to the commencement of the experiment.

Earlier reports by Topper (2002), noted that damage by *A. trifasciata* was mainly seen in Nigeria, even though it has been reported, as being a problem in all the five African countries surveyed. However, the relative distribution of the beetle in 22 out of the 25 States surveyed corroborates the above report. *Analeptes trifasciata* was also found on cashew in Afram plains, Ga districts and some parts of central region of Ghana (Dwomoh *et al*., 2008).

The seasonal occurrence of the beetles observed in both locations differs from earlier reports by Adeyemo, (1988a), which recorded June/July as the peak period of the beetle in the cashew plots. Also Igboekwe, (1983), reported slight peak population of the beetle in July followed by a peak population in November. The beetles were found on mature cashew trees from January to April in Bole, Damongo, Tabiasi and Drobo districts of Ghana (Dwomoh *et al*., 2008). However, it is worthy to note that with good

farm sanitation put in place in the course of this study, the relatively high population of the beetles reported earlier between May to August each year was drastically reduced. All the hanging girdled branches and those fallen to the ground were removed from the cashew plots on monthly basis and burnt, which tremendously reduced the rate of re-infestation. The snapped fallen and hanging branches are known to be the breeding sites for the pest, so removal and burning them outside the plantation would destroy the eggs, larvae and pupae, thereby reducing future infestation by the adult insect. An earlier report by Igboekkwe, (1984) on the control off this beetle through farm sanitation methods showed that the percentage of infested trees in a cashew plot was reduced from 20.99% to 7.17%.

Cashew trees damaged by the beetle have a characteristic appearance. The adult beetle encircles deep grooves on the branches and stems leaving thin woody tissue at the centre to temporarily support the weight of the branch. According to Adeyemo and Okelana (1989), when the cashew vascular tissues are damaged, the ascent of the plant sap is arrested and the twigs dry out, while the leaves becomes yellow and are shed. Such girdled branches eventually snap and either fall to the ground or remain hanging on top of the cashew canopy. This results in a serious economic loss to the farmers; as all the flowers, pseudo apples, nuts and ripe apples on such branches are lost. The stumps of cut or snapped branches generally regenerate and produce many side shoots giving an untidy appearance. The regenerated flushy shoots attract foliar pests, which damages the apical portion and reduce photosynthetic activities of the tree. Such side shoots if not pruned immediately result in overcrowded stems with etiolated growth, which produce little or no fruits on them.

The large numbers of girdled stems hanging on treetops and beyond hand reach after snapping make it very difficult to eradicate this pest from cashew plantations. Their eggs develop unhindered on such stems hanging on treetop until the metamorphosis is complete shortly or after the branches decays and fall to the ground on their own resulting in reinfestation of the plots by another generation of the insect. However, according to Adeyemo and Okelana (1989), the number and duration of the larval instars as well as the papal period are not yet known. Unfortunately, farmers find it difficult to afford the extra costs required to remove these hanging branches from the treetop. The

girdling and snapping of the cashew branches usually occur during the flowering period of cashew. The farmers at this period do not usually bother to remove the hanging branches to avoid high flower shedding that could occur in the process of pulling down the braches. The high number of girdled vertical branches recorded could also be attributed as the reason why most of the girdled branches hang on the treetop, as snapped horizontal branches will easily fall down to the ground compared to the vertical branches.

The height, at which the beetles girdle, oviposits and feeds makes physical control by handpicking very difficult. It is also the reason why most of the girdled branches do not fall to the ground and cannot be easily removed from the treetops. Such cut stems gets entangled in the lower secondary branches of the cashew tree, which prevents it from fallen to the ground. The main essence of girdling by the insect is for reproductive purposes, as that provides suitable breeding materials for the larvae in the form of dead wood. According to Adeyemo and Okelana (1989), the females lay its eggs in the excavated holes made on the bark of the cashew branches with her ovipositor. The eggs are laid singly on part of the stems above the girdled portion and on freshly cut branches still hanging on the tree or fallen to the ground. It has been observed that a heavily infested branch could contain up to eighty (80) eggs (Igboekwe, 1982). The eggs hatch into tiny dull white larvae, which bore into the wood. The larva feeds on dead cashew wood and moults several times before pupating. After about six months, the numerous larvae would have reduced the girdled branch to a hollow shell. The pupal shell or case containing the pupa is located inside the wood of the stem.

Various authors have reported the presence and activities of some other stem borers on tree crops. For example, Daramola (1978) and Ojo (1981) reported that the larvae of *Tragocephala castnia* Thoms. (Coleoptera: Cerambycidae) were found to bore into the stems of kola and cocoa trees. Ndubuaku (1989) reported *Phosphorus virescens* and *Phosphorus gabonator* (Coleoptera: Cerambycidae) as two species of stem borers affecting kola trees, which have been occasionally seen in cocoa farms. *Apate monachus* F. (Coleoptera: Bostrychidae), a polyphagous pest, was reported as a minor pest attacking the trunks of robusta coffee in Nigeria (Okelana, 1989). *Plocaederus ferrugineus* L is a serious pest of cashew that is capable of killing the trees outright. The females lay eggs into the loose bark in the trunk or other exposed portion of the roots of cashew trees. The

grubs that hatch out bore through the bark and feed on the soft tissues. The attack could be identified by presence of small holes in the collar region, gum exudates, extrusion of chewed up fibres and excreta and discolouration of bark. Their activities usually result in yellowing of the leaves followed by drying of branches and finally resulting in the death of the tree (Bhaskara-Rao, 1998; Asogwa *et al*., 2009). The larvae of *Apate terebrans* (Coleoptera: Bostrychidae) develop in a variety of living trees (Topper 2002). The adults also feed on the wood and they can easily damage and kill the trees. Some of these borers according to Hills and Waller (1988) attacks coffee, citrus, cocoa, guava, cotton and other plants. *Eulophonotus myrmeleon* Fldr. (Lepidoptera: Cossidae) was only documented as one of the insect pests found in cocoa rehabilitated plot at CRIN (Okelana 1989). However, in recent times, it has been observed that damage caused by the borer, is becoming increasingly important (Anikwe *et al*., 2006). Damage caused by *E. myrmeleon* on rehabilitated cocoa plots was very devastating during the peak of the rainy season.

The specific characteristic of girdling is the major difference between the cashew stem girdler (*A. trifasciata*) and other known stem borers like *Plocaederus ferrugineus* L, *Eulophonotus myrmeleon, Phosphorus virescens, Phosphorus gabonator*, *Tragocephala castnia; Apate terebrans* and *Apate monachus*. These borers bores, feeds, oviposits and complete their metamorphosis inside living tissues of the cashew, cocoa, kola, coffee or other tree crops (Daramola, 1978; Ojo, 1981; Hill and Waller, 1988; Ndubuaku, 1989; Okelana, 1989; Bhaskara-Rao, 1998; Topper, 2002; Anikwe *et al*., 2006; Asogwa *et al*., 2009). However, *A. trifasciata* completes its metamorphosis in snapped dead and decomposed cashew branches.

Ecological studies often require reliable methods of segregating the sexes of the insect pest under investigation in the field. The morphological characters were therefore assessed to separate the sexes of *A. trifasciata*. However, external physical observation of the last abdominal segment of the beetle was the simplest and reliable means of segregating the sexes. The females were found to possess a mid ventral structure (under which the ovipositor is embedded) on their last abdominal sternum, which was absent in the males. This structural contrast was confirmed on dissecting the adults and is therefore being used as a satisfactory criterion for segregating the sexes. The females were considerably heavier and also have longer abdomen and elytra with a wider last

abdominal sternum than the males, which could be attributed to their reproductive functions. However, other morphometric parameters (length of head capsule, width of abdomen, length of thorax, width of thorax, length of body, width of elytra, length and width of membraneous wings) of both males and females overlap considerably.

The adult beetles of *A. trifasciata* feeds only on cashew stems and is never seen eating the leaves, flowers, pseudo apple or nuts of the cashew plant. The beetles scrape off the stem bark thereby leaving many scattered parchments on it, which distort the mineral transportation activities of the phloem and xylem of the stem. This observation was also corroborated by recent report by Dwomoh *et al*., (2008) that the beetles feed on the branches of cashew trees in Ghana, leaving rings around them and sometimes cutting through the phloem tissues. The report of this study goes further to confirm that the beetles do not feed on any other part of the cashew tree other than the stems, hence the name cashew stem girdler.

The two host plants *(A. occidentale* and *S. mombin*) therefore could be regarded as the main host plants of *A. trifasciata* in Nigeria. The next preferred host plant by the beetles after *them were L. welwitschil*, followed by *T. catappa, E.* sp and *R. heudelotii*. *Theobroma cacao* and *M. esculenta* had the lowest number of beetles found feeding on them throughout the experimental period (EP) and could be referred to as the non-prefered host plants. *Manihot esculenta* and *Theobroma cacao* were reported earlier by Igboekwe, (1984) as host plants of *A. trifasciata*. However, in all the areas surveyed in this study, the beetles were not found feeding on cocoa or cassava in their natural habitat. This observation in cocoa and cassava plantations surveyed was also corroborated by the result of the feeding preference tests as the number of beetles found feeding on the other entire host plants differed significantly from what was found on cocoa and cassava stems.

The protection of agricultural crops and produce over the years was accomplished almost entirely through the use of synthetic insecticides (Adams, 1976; Haliscak and Beenman, 1983; Ivbijaro, 1990; Lale and Efeovbokhan, 1991). But these synthetic chemicals are not without their own short – comings. Synthetic pesticides, while valued for effectiveness and convenience, can pose serious problems, including phytotoxicity and toxicity to non-target organisms, environmental degradation and health hazards to farmers. They also may accelerate development of the pest biotypes resistant to specific

pesticidal chemicals. In developing countries like Nigeria, additional problems include non-availability of suitable materials and application equipment, uncertainties of supply, high costs and inadequate knowledge by farmers about proper use of pesticide products (Metcalf, 1980; Perkins, 1982; Ahmed *et al*., 1984; Sighamony *et al*., 1986; lvbijaro and Agbaje, 1986; Lale, 1995; Adedire and Ajayi, 1996). The peak period of infestation by *A. trifasciata* is usually during the flowering and fruiting period of cashew. Therefore, the application of insecticides late in the season may result to the contamination of the cashew apples, which may be eaten fresh (Boma and Topper, 1998). Also the fact that *A. trifasciata* is a low-density pest, makes the use of insecticides for their control highly ineffective and uneconomical.

There is therefore the need for the evolution of an integrated pest management (IPM) strategy for the control of this noxious pest of cashew (*A. trifasciata*). Such strategy should involve the minimal use or no insecticides as their use are usually associated with phytotoxicity, vertebrate toxicity, pest resistance and resurgence, wide spread environmental hazards and high costs of synthetic insecticides (Olaifa *et al*., 1987; Ewete *et al*., 1996a; 1996b). A proposed option for combating *A. trifasciata* is by the use of insect growth regulators (IGR's), which are chemical compounds that alter growth and development in insects. The IGR's disrupt insect growth and development in insects. The IGR's disrupt insect growth and development in three ways (i.e. as Juvenile hormones, Precocenes and Chitin synthesis inhibitors) (Ware and Whitacre, 2004). The juvenoids or juvegens disrupt development of the immature insect stages and their emergence as adults.

Prococenes interfere with normal function of glands that produce juvenile hormones, and Chitin synthesis inhibitors affect the ability of insects to produce new exoskeleton when moulting. The IGR's does not kill the insects directly; rather it interferes in their normal mechanism of development and may prevent the insects from reaching the adult stage or force them to reach the adult stage before they are capable of reproducing (Ware and Whitacre, 2004; Fishel, 2005). The IGR's are effective when applied in very minute quantities and generally have few or no effects on humans and wildlife. They are practically applied on crops with the purpose of preventing pupal

development or adult emergence, thus keeping the insects in the immature stages resulting eventually in their deaths.

The observation of strict cultural practices as was observed in this study seems to be an immediate solution to control of the menace of *A. trifasciata* for now pending the full development of the techniques recommended above. Farm sanitation involving regular clearing of weeds, handpicking of the beetles and removal of girdled stems containing the eggs and progenies of the pest from the plantation and destruction of their developmental stages by burning such stems outside the plantation is so far the key control measure for the pest. The removal of the hanging girdled branches from the treetop is very tedious and involves extra cost, which always makes it very difficult for farmers to carry out the operation judiciously. Also the peak period of *A. trifasciata* infestation usually occur during the flowering and fruiting period of cashew. The farmers at this period do not bother at all to remove the hanging branches to avoid high flower abortion that could occur in the process of pulling down the braches. Earlier reports from Cote d' Ivoire and Nigeria suggested the use of farm sanitation method for the control of *A. trifasciata*, based on the knowledge of their nature of damage and oviposition sites (Brunck and Fabre, 1970; Igboekwe, 1982). Studies by Igboekwe (1987) on the control of this beetle through farm sanitation methods in cashew plantations at Onigambari showed that the percentage of infested trees in a cashew plot was reduced from 20.99% to 7.17%. This was achieved solely by regular removal and collection of all the hanging girdled branches and those fallen to the ground outside the cashew plots where they were burnt. These farm sanitation/cultural methods can be effectively utilized for all the major and minor pests of cashew. This report was corroborated by the findings in the present study of a high number of girdled branches in January at Ochaja, which was fallout from the previous year's infestation of the plots due to the fact that there was no cultural control programme in place prior to the commencement of the experiment.

The identification and knowledge of the location of these alternate hosts should facilitate the formulation of effective control strategies for the pest. For example, spot sprays of the insect on the alternate host plants may reduce its population in the environment. Also cutting down of such host plants within the vicinity will reduce or eliminate sources of reinfestation of cashew trees.

CHAPTER 6
SUMMARY AND CONCLUSIONS

Cashew is an important export crop in Southern Asia, Brazil, India and parts of Africa. It is a very important economic crop to the livelihood of many Nigerian farmers. During the last five to ten years, Nigeria has emerged as a leading producer of cashew nuts in Africa and the second world producer. However, these great production potentials of cashew in Nigeria are not without its own shortcomings. The associated insect pest problems have consistently posed a great challenge to the productivity of the crop in Nigeria.

This study, which was carried out between 2005 and 2008 was aimed at generating baseline data on the cashew stem girdler, *Analeptes trifasciata* as scientific information on most aspects of this pest in Nigeria are very scanty. The study focused mainly on the aspects of the morphology, ecology and feeding behaviour of the pest.

The findings from this study were summarized below:

1. The fully developed adult *A. trifasciata* has an average body length of 3.96cm and its antennal length is longer than the body.
2. *Analeptes trifasciata* is a low-density pest that are found in pairs (males and females are always together).
3. The highest infestation rate of 82.6% was recorded at Kogi State, which was closely followed by Oyo (79.3%), Abia (62.4%), Imo (61.3%), Osun (61%) and Anambra (59.3%).
4. The insect were not found in Akwa-Ibom, Bayelsa and Rivers States. A very low rate of infestation was recorded for Plateau (5.6%), FCT (8%), Niger (12.5%), Taraba (12.7%), Kaduna (13%) and Enugu (13.7%).
5. The number of *A. trifasciata* girdled branches collected at Ochaja plots (535.8 ± 27.6) differed significantly ($P < 0.05$) from that of Ibadan plots (323.7 ± 18.4).
6. The cashew trees at Ochaja experimental plots were totally infested (100%) by *A. trifasciata* within the experimental period. However, an infestation rate

of 84.3% was recorded at Ibadan plots, which was not significantly different from that of Ochaja plots.

7. Peak of infestation (117-130 *Analeptes*) per plot was recorded from September to December, with very low infestation (7 *Analeptes*) per plot in June.
8. The population of the pest was relatively higher at Ibadan cashew plots (554.3 ± 41.3) compared to Ochaja plots (360.7 ± 42.4).
9. The mean monthly population count of *A. trifasciata* at Ibadan (276.7±5.0 males and 277.7±15.6 females) and Ochaja (179.7±11.1 males and 181.0±10.2 females) cashew plots showed no significant difference between the number of males and females collected.
10. The girdling of cashew branches by *A. trifasciata* results in drying out of the stems from the point of girdling. Some of the girdled stems snap and either hang on cashew tree tops or fall to the ground.
11. In some cases, the girdled cashew branch recovers by producing a lot of gum exudates around the girdled portion, followed by an outgrowth to heal the wound.
12. *Analeptes trifasciata* feed by scraping the bark of the cashew stems and usually mate and lay their eggs below the bark above the girdled portion of the cashew branch that will hang or fall to the ground.
13. The mean number of girdled stem still hanging on top of the tree canopies at Ibadan (273.3±14.9) significantly differed ($p < 0.05$) from those fallen to the ground (212.0±17.9).
14. However, at Ochaja plots a mean number of 413.7±62.9 hanging branches and 390.0±11.8 fallen branches were recorded, which showed no significant difference.
15. A higher mean number of girdled branches (803.7±41.3) were recorded at Ochaja plots when compared with 485.3±25.2 at Ibadan plots, which was highly significant.
16. However, at Ibadan cashew plots the mean number of girdled vertical branches (243.3±20.2) did not differ significantly from the girdled horizontal

branches (243.0±6.5). The trend was same at Ochaja plots where the girdled vertical branches (386.7±13.9) showed no significant difference from the girdled horizontal branches (417.0±22.3).

17. The pest was found to prefer medium to moderately tall trees within the range of 2m to 4.99m heights, as they did not attack the very low and tall trees.
18. The insect girdled medium sized cashew branches within the ranges of 3.0cm to 6.99cm. However, over 50% of the girdled stems were within the diameter range of 4.0cm to 5.99cm.
19. A very significant number of the beetles ($P < 0.05$) consistently fed on the cashew stems for the whole 24 hours experimental period (EP), and no feeding signs were observed on the leaves, flowers, fruits and nuts after the 24 hours EP.
20. *Anarcardium occidentale* and *Spondias mombin*, had the highest number of beetles found feeding on them for the whole 24 hours experimental period (EP), which differed significantly ($P < 0.05$) from those found on all the other host plant food sources.

In conclusion, it is obvious from this study that *Analeptes trifasciata* is indeed a major pest of cashew in Nigeria. There is therefore an urgent need to develop a comprehensive control package for the pest.

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