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Insect pests and its control of Coffee - A Review

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Abstract

This review report explicitly explained Tea, *Camellia sinensis* L. that thrives on high altitude region of Mambilla Plateau in Nigeria. Though its production has, however, been limited to the mountains area of Mambilla plateau, Taraba State. The annual tea leaf yield from the Mambilla has become grossly too low to meet the growing market demand for tea. It becomes imperative to increase area of tea cultivation across South Western Nigeria with different agro-ecosystem. Several insect pests have been identified in tea tree plantations and however, the full pest complex of tea tree remains unknown and the magnitude of any pest attack depends on weather conditions. Only a small number out of 100 insect species found in tea tree plantations are considered as significant pests by tea tree growers e.g. pyrgo beetle, grasshoppers and plant bugs (borers). The injuries caused by pyrgo beetle, grasshoppers and plant bugs pests result in the development of lesions and necrosis at injured sites, wilting of plant, die-back, fungal attack, and in severe infestations, death of the plant. However, in the intensive cultivation and production in Nigeria, some of the insect pests which currently appear to be minor may become major pests, with attendant modifications of the tea agro-ecosystem. Therefore, major control methods of the various insect pests were examined, in relation to cultural operations and environmental factors associated with tea production. Cultural operations such as pruning cycle, leaf plucking and host -plant factors including the nutritional status and the presence or absence of certain flavour compounds in tea plants were properly examined.

Keywords: Insect pests; Cola spp; Damage characteristics; Control measures; Field; Storage pests

Abbreviations: NBPC: Nigerian Beverages Production Company; CRIN: Cocoa Research Institute of Nigeria; IPM: Integrated pest management

Introduction

Tea, *Camellia sinensis (L)* O. Kuntze is a plant specie, which belongs to the family Theaccae, which encompasses some 200 woody plant species in the warmer regions of Asia and South America (Steele, 1976; Opeke,1987). Within the species, one may distinguish the 'China teas', slow growing dwarf tree with good tolerance of cold weather and other adverse conditions snd 'Assam teas', which are faster growing teas adapted to warmer conditions (Steele, 1976; Opeke, 1987). Cultivation of the tea plant is restricted to subtropical regions and mountainous areas of the tropics, where altitudes are in the range of 1200-1800 m above sea level with temperature regimes of 10C to 27C without frost. This explains why tea can be expected to perform well at very few locations in West Africa. For example, only towards the eastern border of Nigeria does the Mambilla plateau attain sufficient height to allow for tea cultivation. Further east, in Cameroon, several sites could be available, but these are outside the areas presently considered. Further West, the higher areas either lack the rainfall required for successful tea production or the soils are unsatisfactory, an example in Jos plateau in Nigeria. The plant requires high rainfall and humidity almost throughout the year. An annual rainfall lower than 1100 mm is considered marginal. Soils for tea should be deep, well drained and must be acidic. These conditions are identical to those obtained on the Mambilla plateau of Taraba State and riverine areas of the Southern part of Nigeria. Infact a few scattered stands of old tea bushes, the origin of which had been a subject of speculation, had been found on the Mambilla. They are thought to have been introduced about the same time that De Bouley introduced coffee to the plateau from West Cameroon in 1952 (Filani et al., 1989). Following favourable reports on the feasibility of tea production in Nigeria by consultants in 1973, the first consignment of nine commercial clones was imported into the plateau in 1975 exclusively from the African continent since a complete ban had been imposed on importation from far East by Inter African Phytosanitary Council (Hainsworth, 1981). Since that time, more clones have been imported and a large-scale commercial plantation developed with an adjoining processing factory owned by the Nigerian Beverages Production Company (NBPC) at Ardo Gori.

Today substantial tea production is being undertaken by appointed native out growers and Nigeria-made tea otherwise known as 'Highland Tea' from Ardo Gori is available in most rural and urban centres in Nigeria. The Cocoa Research Institute of Nigeria (CRIN) has played a most significant role in the development of the tea industry by conducting research into various production aspects, thus providing technical information and support to farmers and companies engaged in tea production since July 1982. So far in Nigeria, the tea plant is mainly important for its leaves whose extracts are incorporated in several brands of tea beverages produced in the country by the NBPC and many other companies. High quality oil can also be extracted from the seed kernel of tea plants and the seed hulls can also be utilized for livestock feeding purposes (Egbe and Sobamiwa, 1989; Adesioye, 1990). The tea kernel contains 1.46 refractive index, 0.88-0.99 ml by density, 18.64-37.71%, crude fat, 3.28-3.50%, crude fibre and 0.81-0.97% free fatty acids. The above results of physico-chemical analysis showed the potential of tea kernel oil as an edible oil (Adesioye, 1980). There have been the diversification of the product range of tea as a health food drink to include medicinal preparations (Jeremiah, 1995), and other forms of beverages like instant tea, tea cola, iced tea and tea blends with mistletoe. These could open up other markets, and thus help to improve demand and profits to tea farming (Owuor et al., 1986; Akiwale et al., 2000).

Major field insect pest of Tea

Tea mosquitos, Helopeltis scoutedeni (Hemiptera: Byocorinae)

Importance: Mature bug is slender and a sporadic pest, which can cause serious damage to tea leaves. They also attack many other plants including cotton, avocado, mango, guava, cashew, cocoa, potatoes, pepper etc. A severe attack will result in up to 80% of damaged branches (Rickson and Rickson, 1998).

Biology: The egg hatches within two weeks into nymphs, which undergoes five nymphal instars within 3 weeks. A total of 30-60 eggs are laid by each female, which may live for 6-10 weeks.

Damage: Young nymphs feed on the underside of leaves while older nymphs feed on young shoots and developing fruits. Feeding on the leaf may cause cessation of growth and crinkling or even death to the affected part (Ohler, 1988). Both adults and nymphs feed suck the sap from tender shoots, floral parts, and even from immature nuts and apples (Ranaweera, 2000). Attacked inflorescences usually turn black and die. During feeding, the insect injects toxic saliva into the plant causing death of the plant tissue. Black necrotic lesions and sunken spots can be seen at the site of feeding (apples and nuts). The plants may also become stunted and the edges of the leaves may curl downwards.

Control measures

a) Chemical control: According to KAU, (2002), the control of tea mosquito bug can be done by spraying 0.05% Endosulfan or 0.01% Carbaryl or 0.05% Quinalphos or 0.03% Phosphamidon. Also, Dioxocarb was recommended for the Tea mosquitos, *H. scoutedeni*. Effective control was achieved with these insecticides by spraying them onto the undersurface of the leaves and immature pods.

b) Cultural method: Farm sanitation involves the removal of damaged shoots 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. Pruning might be beneficial for the control of the insect. Removal of non-productive and diseased branches from the trees allows for improved air circulation and solar radiation within the crop canopy which reduces the humidity of the canopy. This farm sanitation method is encouraged for all the insect pests of cashew, coffee, kola and tea.

Aspavia armigera

Importance: It is found throughout Nigeria. It attacks tea crop and other arable crops like rice, cowpea, cotton, sorghum and benniseed.

Biology: Eggs are laid on leaves and stems i.e., shoot of plants. The eggs hatched in about 7 days and the nymphs develop through several instars over 4-6 weeks to become adults.

Damage Characteristics: Adults and nymphs suck sap from the plant. They attack the developing seed heads, stems and foliage. The attack results in empty grains and defoliated leaves of low quality. In case of rice however punctured grains turn black.

Control measures

a) Cultural control: Grassy weeds should be eliminated from farms, and staggered planting should be avoided. Also, the use of resistant varieties or early maturing varieties and early planting are recommended. There good cultural practices are essential to maintain natural enemy populations below economic threshold levels.

b) Chemical control: An economic threshold of about 10 insects per 20 plants is used. Effective chemicals include monocrotophos, dichlorovos, fenthion, azinphos-methyl. And phosphamidon.

Zonocerus variegatus L.

Importance: *Zonocerus variegatus L.* is found throughout West Africa, South of the Sahara spreading Eastwards of Uganda and northwards into Sudan Page [1]. Youdeowei [2] has produced a map of the distribution of the two species of *Zonocerus* (*Z. variegatus* and *Z. elegans*), which occurs in Africa. According to Page [1], *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, they are found all over grassland areas, and Toye [3] reported that *Z. variegatus* usually occurs in cultivated land with nymphs and adults sharing the same habitat and its habitat extends from the lowland rain forest zone to the Guinea savannah in the north. Two distinct populations of

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Z. variegatus exist in southern Nigeria Toye [3]; Taylor [4]; Anya [5] and Youdeowei [2]. These are typically referred to as the dry and wet season populations. In South West, Ibadan area, the populations of *Z. variegatus* may be found throughout the year. The population found during the wet season (April-October) is small, while the dry season population (November-March) can be very large Page [1]. Therefore, the occasional outbreaks of grasshopper can cause serious damage to tea crops. They are of various species, which includes; Comphosene producta Wlk (Orthoptera: Pyrogomophidae); Attractomorpha aberans Karsch (Orthoptera: Pyrogomophidae).

Biology: In South West, Nigeria, adult *Zonocerus* variegatus becomes 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 occuring during the first week in April, but do not hatch until late October or November with embryonic development, which includes diapauses taking 6-7 months Entwistle [6]; Page [1]; Omole [7]. In Eastern Nigeria, there is one annual generation but two definite broods, most eggs being laid in March/April and August/ September. Each female lays 1-4 egg pods, which is 40-45 mm long, each containing 20-90 eggs. The pods are buried 5-8 cm deep in the soil. As many as 3,500 pods have been found on a site of 16 m^2 Toye [8]. This shows that egg pods are normally concentrated in selected egg-laying sites. The egg development is dependent on high level of soil moisture and takes place at the end of the wet season. *Zonocerus* variegatus generally has six nymphal instars in the field although a small percentage of the insect will have only five instars Chapman et al. [9]. The nymphal development proceeds during the dry season and adults are dead before the next rain or at the onset Entwistle [6]; Toye [8]. Lee and Wood [10] stated that as plant tissue is either directly or indirectly the source of food for termites, vegetation must be an important factor in determining their distribution and abundance.

Damage characteristics: 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 Harris [11]; Malaka [12-14]. The polyphagous pests: *Zonocerus variegatus L.*; Brachytrypes membranaceus Dury and Gryllotalpa africana Beauv, were not left behind as they were seen feeding on kola foliage and young stems causing excessive defoliation and death of seedling plants Daramola [15]. The females deposit egg capsules in the soil during the rainy season. The eggs hatch and nymphs appear in November, while adults emerge in late January to March Daramola [15]; Toye [8]. 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, leaving the veins intact, especially of seedlings. Both the nymphs and adults feed on new flushes, moving from one plant to the other after stripping the former bare. Their feeding activities always result in severe damages to young kola stands. Grasshoppers are known to feed on wide range of plants, showing preference to various annual herbs. Field observations on the damage caused to economic crops in Nigeria by *Z. variegatus* have been recorded by several authors Toye [16,17]; Anya [5]; Youdeowei [2]; COPR [18,19]; Page [1]; Omole [7]. They all have illustrated accounts of the nature of damages to important economic crops such as banana, plantain, cassava, citrus, cocoa, kola, cotton, cashew, cowpea, tea etc.

Control measures

a) **Cultural control:** Toye [8] however reported that control operations on grasshopper should be carried out in November and early December when young nymphal aggregations are dense. A drastic reduction of the *Zonocerus* population could be achieved by digging up the egg laying sites and exposing them to 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 [1]; Toye [8]. According to the COPR [20], it is possible to reduce a *Zonocerus* population by 90% through this method. Also, studies carried out in two egg-laying areas showed that potential hatches were reduced by 83-91% through exposure of dug egg pods to desiccation Page [1].

b) **Chemical method:** All instars of *Z. variegatus* can be killed easily by the common insecticides (Fenitrothion) using solutions of 0.1% wt/vol. a.i., though 0.5% a.i. could equally achieve effective control on the target. The best time for spraying is in the early mornings or late afternoons when the insects are less active and preferably on the highly aggregated early instars of the insect. However, due to the well 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 [1]; Toye [8]. Ndubuaku [21] effectively controlled nymphal aggregations on weeds with kerosene applied using a motorised mist blower.

Grasshoppers (*Orthoptera: Acrididae*) – They are gregarious and feed on young immature leaves thereby reducing their photosynthetic area and damaging the leaf quality of tea leaves. They are usually brown in colour and mature adults are about 4-6 cm long. Mature females lay their egg pods (which usually contains 80-100 eggs) in shade on abandoned farmlands. In the drier regions of Nigeria, eggs are laid at the end of one raining season and hatch at the beginning of the following year rains. The eggs are encased in a capsule made from the soil to prevent desiccation.

Crematogaster buchneri Gorel

Importance: Ants are general nuisance pests, building nests in trees, biting aggressively and making harvesting difficult.

Biology: Ant colonies have some fertile males called drones and one or more fertile females called queens.

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Damage characteristics: Eguagie [22] reported that the ant, *Crematogaster buchneri Gorel* scrapes off the epidermis of the leaves and follicles of cocoa. The damage usually results in the shedding of leaves and the premature dropping of shrivelled follicles. The associated beneficial insects like scale insects, Stictococcus sjostedti CKII has large colonies whose piercing and sucking feeding injuries cause stunted growth and pod drop. Also, the feeding injury of the mealybugs, Planococcus citri Risso; Planococcus njalensis Laing; Ferrisiana virgata CKII on the cocoa flowers, flower stalk and pods, impair fruit development Ndubuaku [21].

Control measures

a) **Cultural method:** Farm sanitation like pruning and shade management is effective in insect management.

b) **Chemical method:** Aldrex 40 is proven effective for the control of insect.

Ancistrotermes spp, Amitermes spp, Captotermes spp and Macrotermes spp

Importance: *Ancistrtermes spp, Amitermes spp, Captotermes spp and Macrotermes spp* (Termite) colonies are started by the sexual forms, which fly from the nests at the start of the rainy season and lose their wings before re-entering the soil or other hiding places NRI [23]. Termite, Macrotermes bellicosus, is however an emerging pest of Cocoa tree plantation.

Biology: Termites undergo incomplete metamorphosis; the younger instars of their nymphs greatly resemble the adults and take on important functions in the nest at an early stage Kranz [24]; Malaka [14]; Pearce [25]. Copulation is eventually accomplished and eggs laid into excavated initial cell which terminated courtship in termites. In an established colony, the queen lays egg and the eggs may be carried by the workers to other chambers or to a separate part of the royal chamber during incubation for hatching. 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 who looks after and clean them, until the first workers develop to take on the role of foraging for food and looking after the young ones.

Damage characteristics: Termites cause damages on the field by attacking the trunks and pods of cocoa/kola tree causing the plant and the pods to dry up after severe infestations. They feed on dead vegetation and tunnel into the roots and stems of trees of any age resulting in destruction by weakening of the tree structure causing them to collapse or giving access to the entry of pathogenic organism (fungus and other diseases). The fungal pathogen is responsible for rot infection. Other insect damage activities included bark nibbling and scraping, which can cause the death of seedling and even mature plants. Damage is most severe in stands which are under severe water stress, old stands and those subjected to bad pruning which leaves dead and dying tissue on the plant NRI [23].

Control measures

a) **Cultural method:** Crop rotation or rotational cropping system is effective in the control of the subterranean insect pest. Avoid continuous cultivation on the same area of land to prevent the termite population build up.

b) **Chemical method:** Termites could effectively be controlled by the application of insecticides (Methidathion,Carbofuran, Endosulfan, Pyrinex, Dursban, Termicid, Endocarp and Fenitrothion) to the soil around the base of the kola seedlings and mature plants or coppiced stems just before the outset of the dry season NRI [23]; Adejumo and Asogwa [26]. Oyedokun et al. [27] reported that the aqueous extracts of Phyllanthus amarus, Acassia albida and Tithonia diversifolia caused 40-56%, 24-60% and 42-88% mortality of termite, after 140 minutes of exposure (MOE) to the extracts. Similarly, ethanolic extracts of the P. amarus, A. albida and T. diversifolia resulted in a significantly ($P<0.05$) higher percentage mean mortality of 64-91%, 36.4-76% and 36-68% respectively.

General control of insect pest damages

The following cultural, chemical, botanical, integrated Pest Management (IPM) strategy and legislative control measures have been proposed and perfected for the control of insect pests of Cocoa, Kola, Coffee and Tea. These measures are also applicable to all economic crops (Table 1).

Cultural control measures

These involve the use of simple cultural practices such as farm sanitation, physical removal and killing of insects, controlled burning, shifting cultivation, crop rotation, intercropping and interplanting, tillage practices, use of shade crops, use of alternative hosts, pruning and excision, timely and prompt harvesting, processing outside the farms etc. These cultural operations are very cheap and stabilize the populations of most insect pests below their economic threshold. The practices are also human and environmentally friendly and do not have any side effects. Some of the cultural practices are as follows:

i. **Use of shade crops** – Cultural operations involving the utilization of shade plants in young and old cocoa and kola plantations have been comprehensively researched upon. Filling up of gaps in mature and rehabilitated farms reduce the formation of capsids (mirid) pockets. Also, regular removal of basal chupons and infested cherelles and young cacao pods deprive various insect pests of cocoa such as capsids, shield bugs, mealybugs, psyllids and most other shoot feeders of suitable feeding and breeding sites. Consequently, suppression of the rapid build-up of their populations is usually experienced. Adequate provision of shade and timely removal of infested seedlings also reduce infestation and activities of root feeding termites in newly established and young cacao, coffee, cashew, kola and tea plantations.

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Table 1: Insect pests associated with tea in Nigeria.

No.	Insect pests (Scientific names)	Common names	Order	Family	Type	Pest category	Plant parts attacked
1	*Comphosens producta Wlk*	*Grasshopper*	Orthoptera	*Acrididae*	Field	Major	Shoot/leaves
2	*Attractomorpha aberans Karsch*	*Grasshopper*	Orthoptera	*Pyrgomophidae*	Field	Major	Shoot/leaves
3	*Lagria villosa Schaus*	*Leaf beetle*	Coleoptera	*Lagridae*	Field	Major	Shoot/leaves
4	*Helopeltis schoutedeni*	*Tea mosquito*	Hemiptera	*Byocorinae*	Field	Major	Shoots
5	*Gryllus domesticus*	*Crikets*	Orthoptera	*Grylotalpidae*	Field	Major	Shoot/root
6	*Lygaeus festivus*	*Sap suckers*	Hemiptera	*Lygasidae*	Field	Minor	Shoot/leaves
7	*Dysdercus supersitious*	*Cotton stainer*	Heteroptera	*Pyrhocoridae*	Field	Minor	Shoot/leaves
8	*Aspavia armigera*	*Shield bug*	Heteroptera	*Pentatomidae*	Field	Minor	Shoot/leaves
9	*Rutidoderes sqarrosus*	*Grasshopper*	Orthoptera	*Pyrrgomorphidae*	Field	Minor	Shoot/leaves
10	*Ceroplastes spp*	*Scale insect*	Hemiptera	*Coccidae*	Field	Minor	Shoot/leaves
11	*Brachytrypes menbranaceus Drury*	*Crickets*	Orthoptera	*Gryllidae*	Field	Minor	Shoot/root
12	*Acanthopysche spp*	*Bagworms*	Lepidoptera	*Psychidae*	Field	Minor	Shoot/leaves
13	*Nasutitermes spp.*	*Termites*	Isoptera	*Termitidae*	Field	Minor	Shoot/root
14	*Pseudocrobotra ocellata*	*Ant*	Dictyoptera	*Hymenopodidae*	Field	Minor	Shoot/leaves
15	*Atelocera spp*	-	Hemiptera	*Pentatominae*	Field	Minor	Shoot/leaves
16	*Plectrocennis oblongipes*	-	Hemiptera	*Coreidae*	Field	Minor	Shoot/leaves

Source: Asogwa [31].

Young cocoa needs shade for quick establishment. Experience has shown that farmers prefer to use recommended nurse shade plants which have economic value as they give the farmer some income before the cocoa begins to yield fruit. Farmers in Nigeria, Ghana, Cameroon and Ivory Coast who produce 70 per cent of the world's cocoa, are peasant farmers with very small holdings. They need money during the period of establishment to supplement their meager incomes, to assist in helping to discharge their civic duties, such as payment of taxes and above all, pay the school fees of their children.

ii. Crop processing outside the farms - Preliminary processing of these crops are usually carried out in the area around the farms before taking them to the store or market. Such preliminary processing should best be done outside the farm environment to reduce the chances of reinfestation of the farms from already infested produce. For instance, the cocoa pods should be broken and processed outside the farm at the pod breaking dumps. Also, the dehusking of kola pods far away from kola grooves and burying of pod husks which harbour developing larvae will reduce the level of the kola pod borer, Characoma stictigrapta population.

iii. Prompt harvesting – Cultural practices involving early harvesting of mature kola pods prompt removal of fallen and hanging mature pods at the end of the season, as well as the removal of dead and moribund pods between crops have been suggested as effective and economic methods of reducing the level of insect pest infestation in kola. Also, timely harvesting of coffee cherries minimizes the quantitiy of cherries that drops into the litter, as these serve as pest reservoir for future attack. Also prompt harvesting of late maturing cherries left after the main harvest on regular basis is very effective but labour-intensive. The practice ensures that no coffee borer remains in the plantation after the season.

iv. Physical removal – Hand picking and subsequent destruction of the later instar larvae of the foliar pests of coffee, *Epicampoptera spp and Cephanodes hylas* and pupae of the former have been found to effect control of these pests to some extent. The same applies to the kola stem borers, Phosphorous virescens. It has been observed that if the canopy of an infested kola tree is shaken or beaten, adult stem borers tend to drop to the ground and feign death. In the morning hours (7-11 am) 50-80% will drop instead of fly, while in the afternoon, fewer adults (12-32%) will drop. Hand picking is therefore less labourious and more efficient as a control measure when carried out early in the morning or alternatively the use of other cultural control methods such as poking of larvae of P. virescens in the tunnel with long wires or cutting and removal of stems containing the larvae can be used. This method was found to be very effective even though it is labour intensive. This method has also been utilized for the control of Analeptes trifasciata, which resulted in the drastic reduction of the infestation levels in cashew plot.

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v. Tillage practices – A drastic reduction of the *Zonocerous variegatus* population could be achieved by digging up the egg pods in the egg laying sites around young cocoa, coffee, cashew, kola and tea plots thereby exposing them to high surface temperatures that desiccate the eggs. If all or nearby 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. It is possible to reduce the population by 90% through this method.

vi. Farm sanitation – Based on the knowledge of the nature of damage and oviposition sites of Analeptes trifasciata, the use of farm sanitation method for the control of this pest has remained the best option. 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. This farm sanitation method is encouraged for all the insect pests of cashew, cocoa, coffee, kola and tea.

vii. Pruning and excision – Pruning is usually embarked upon to maintain a good canopy and to achieve tree structure convenient for harvesting and spraying. It usually entails removal of dead, diseased and insect damaged woods, which are destroyed to prevent further pathogen and insect development. This helps to decrease number of primary wood-boring insects and also reduces the number of sites at which termites can gain a foothold. There are two main aspects to termites control in cocoa, coffee, cashew, kola and tea.

a) Prevention of root, collar and basal stem attack in the nursery and in young plants in the field

b) Prevention of termite establishment in wounds and dead wood on mature trees so as to avoid spread of infestation to healthy wood. 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 the treatment of cut and damaged surfaces with paint, coal tar or copper fungicide until they are callused over. The improvement of pruning technique, routine removal of all dead plant parts and manipulation of the shade and soil moisture through intermittent irrigation during the dry season may minimize attack by termites

viii. Use of alternative hosts – With polyphagous insects the wild host plants may be so numerous that special eradication would be impracticable, but where insect pests have a restricted host range, their removal may be especially beneficial. Studies by various workers have produced a long list of alternative-host plants of cashew pests. These includes *Lannae humilus Oliv. (Anarcardiaceae) Spondias mombin L. (Anarcardiaceae), Terminala catappa (L) (Combretaceae) Ficus mucosa (Myrtaceae) Eucalyptus toreticornis (Myrtaceae), Adansonia digitata (Borabacaceae)* and *Ceiba pentandra* for *Analeptes trifasciata* among others. Theobroma cacao and areca nut of betel nut (areca tree) have been identified as alternate host plants of *Selenothrips rubrocintus*, while pawpaw, mango, almond and citrus trees are notable alternate hosts of Pachnoda cordata. These host plants can be manipulated by trapping out the pests away from the main crop plantation. Alternatively, all the alternate host plants within the vicinity of the main crop plantation should be cut down so as to prevent the pests from hibernating on them during the off season in biological reports, plants which tolerate specific phases of the development stages of the insects or serves as temporary source of food and survival are often referred to as alternative host plants, whereas they are better regarded as incidental host plants, fortuitous host plants or trap plants. Typical examples of these cases are

a) Incidental host plant – The activities of some alternative host plants of coffee pests have been reported. Apart from *Gardenia spp*, first reported in 1985 at CRIN, eggs and larvae (1^{st} -4^{th} instars) of *Cephanodes hylas* were seen on young flushes of the single lxora; Ixora coccinea Linn (Rubiaceae) in November 1987. These were, however observed to be very few compared with those on Coffee and Gardenia. This may be due to the limited Ixora foliage available as food for the pest. In addition, *Crematogaster spp. (Hymenoptera; Myrmecinae)*, which abound on the Ixora plant preyed readily on the larvae of the pest and this may largely be responsible for the low incidence of the pest on this plant. The single Ixora therefore may be regarded as an incidental host plant of *C. hylas* and as such, its presence may not likely pose any threatbto coffee cultivation.

b) Fortuitous host plant – The results from comparative laboratory study of the life cycle of *Cephonodes hylas on Coffea canephora; Gardenia ellis; Ixora coccine and Ixora spp* (unidentified) showed that *G. ellis, C. hylas* because the moth completed its life cycle on the plant. The various larval instar and pre-pupae of the pest were of similar size with those bred on coffee. But two Ixora spp. Did not allow the moth to complete its life cycle on them, hence could be regarded as fortuitous host plants of the moth/pest. Furthermore, all the larval instars reared on the Ixora spp. Were highly stunted when compared with those reared on Coffee and Gardenia spp.

©Trap plants – The two *Ixora spp* highlighted above could be employed as trap plants in the control of the pest because these plant species did not support the completion of the pest's life cycle. In general, the alternative host plants of major and minor pests of cocoa, coffee, cashew, kola and tea should be avoided while intercropping their young seedlings with food crops. This deters rapid invasion and multiplication of such pest in such farms. An alternative host plant can be broadly defined as that which tolerates all facets of the insect developmental activities (from egg to adult) in addition to serving as source of food to the various instar stages. It is common in biological studies to often refer plants, which only tolerate some phases of the developmental stages of an insect as an alternative host plant.

ix. Use of cover crops - Any rehabilitation method other than growing young cocoa under old trees increases the weed problem. The area becomes exposed and weeds and pests invade it. To avoid the ingress of grasses, cover crops, some of which may

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have economic value, e.g. beans, melons, could be tried. The use of cover crops will reduce soil erosion which could aggravate the soil fertility problem. Row weeding must, however, be done to keep the immediate surrounding of the cocoa plants free of weeds, thus reducing competition for nutrients. Results of experiments at Kade, Ghana revealed that no particular cover was superior to natural regeneration, although the use of Tephrosia and Indigofera Sumatrana (both legumes) encouraged early and are replaced by natural regeneration. Mulching and use of legume covers gave higher cocoa yield than natural regeneration. This was attributed to better early growth rather than the residual effects of the cover on the soil.

Biological control measure

It entails the use of an organism to control another organism. The population and activity of insect species can be altered through introduction of another organism including bacteria, viruses, insects and other natural enemies may be by introduction or man's intervention with the stable ecological factors (abiotic and biotic factors). The concept of prey-predator relationship gives an overall view of biological control. However, rearing of biological control agents is an expensive venture. In most cases, the nature enemies of the insects within their existing ecological conditions are consciously preserved by man through judicious and selective chemical applications. If need be, thus the concept of integrated pest management gives an adequate protection to the maintenance of natural enemies in their natural environments.

Notable among the predators of the cacao mirids are the tailor ants, *Oecophylla longinoda*, and some species of *Reduviidae, Araneidae, and Mantoidae* families. Also there are some important pathogenic diseases, which attack cacao mirids, these include: *Aspergillus spp, Bauveris spp and Bacillus spp*. Parasitic species of Hymenoptera, a fungus (*Aspergillus spp*) and parasitic nematode were seen parasitizing the larvae and pupae of Characoma stictigrapta in Nigerian cocoa plantations. The build-up in decline of all the parasitic species followed a similar pattern with peaks occurring between August and November coinciding with the period when Characoma larva population was high. The tailor ants, *O. longinoda* were also actively preying on all Characoma larva instars. The braconid egg parasite, *Trissolcus spp (Scelionidae)* and the nymph/adult parasite, Cylindromyia cribrate have been found to parasitise the cacao shield bug, *Bathycoelia thalassina, B. thalassina* and causes about 14% adult parasitism. Also, some predatory insect spp. when caged with various stages of *B. thalassina* were found to feed on the nymphal and adult stages of the pest. These include *Spodromantis lineola, Mionentis pharaonic, Polyspilota aenigionosa (Mantidae); Acanthaspis bilineolata, Sphesianolestes sp. (Reduviidae)*; some ant species; *Paltophyreus tarsatus, Odontomachus haematodus, Oecophylla longinoda* and three unidentified arachnid spider species. It was also noted that a complex species of parasites and predators attack mealy bugs on cacao and but their potency as natural enemies are generally low. Some parasites, which belong to the family, Encyrtidae include; *Leptomastix bifasciatus* (Compere), which formed 25-50% of all primary parasites, and *Neodiscoides martini* (Compere), which accounted for about 15% for all the parasites reared from mealybugs. Notable among the predators of mealybugs are the larvae of Cecidomyiid flies, and the adults and larvae of Coccinellid beetles. These feed mainly on nymphs and adults of mealybugs but the extent to which each of them controls mealybug populations is unknown.

Unprecedented high levels of parasitism of the various developmental stages of the foliar pests of coffee, most especially *Cephonodes hylas* have been reported. The parasite *Telenomus spp. (a Scelionid wasp)*, which parasitizes the foliar insect pests of robusta coffee, ranged from 75-90%, while larval parasitism by *Euplectrus spp*, was about 25% with most (about 70%) of the early instar larvae dying of desiccation. Also, a parasite *Exorista sp. (Tachinidae)* was found attacking the caterpillars of *Parasa euchlora* in coffee fields. In August 1985 adult Tachinid flies were found common in the field hovering over the colonies of the stinging caterpillars in search of the points to lay their parasitic eggs. The eggs remain on the caterpillars till they hatch. The coffee berry borer, *H. hampei* (Ferrari) is indigenous to Central Africa and it is there that three important natural enemies are found. These are two Bethylids: *Prorops nasuta; Cephalonomia spp* and predator. The adult parasite feeds on eggs and young larvae while the larvae attack the fully-grown larvae and pupae of the borer. The larvae of *Cephalonomia spp* lives as ectoparasite on the last stage larvae of the berry borer. The adult of this parasite also lives, in the berries feeding on the predator feed on bugs and aphids on tea. Biological control is now a complete eradication method. The parasite does not completely exterminate the host as it will affect them if they do so. Therefore, biological control is a density dependent affair, but it keeps the pest population to a tolerable level. This method is known to be permanent once it is introduced and established, it is very economical, self-sustaining and highly specific (i.e. predator-prey relationship).

Chemical control measures

Chemical control method is encouraged as the last resort to complement other methods or to address major pest outbreak problems. Presently, conscious efforts are directed towards judicious and selective chemical usage. This will combat the problem of resistance to pest, toxicity to man and tainting of plant products. The pyrethroids, though costly, are considered safer than other class of chemicals including organochlorine, organophosphate, carbamates etc. The chemical control should be at the initial stage of infestation of all the foliar pests since the later stages inflict greater injuries on the plant than the early stages. Spraying of insecticides should be carried out early in the morning or by late evening. The chemical control of cacao pest, and in particular that of cacao mirids and mealy bugs in Nigeria and other West Africa cacao producing countries could be traced back to the period between 1838-44 when the miricidal efficacies of botanicals (Pyrethrum and Derrimac dusts), inorganic salts

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(Nicotine sulphate and lime-sulphur) and old cacao under laboratory and field conditions. Reasonable mirid mortality ranging from 50-70% was recorded. This was followed by the evaluation of organochloride insecticides, chlorinated hydrocarbon insecticides and insecticide applicators which all showed high miricidal efficacy. Unfortunately many of the previously registered, cheap mirid insecticides are no longer allowed on cocoa. Modern and specific pesticides such as imidacloprid are now available but they are very expensive and not always available in the local market. Most rehabilitation procedures will lead to the exposure of the area concerned. Experience at Gambari Experiment Station in Nigeria has shown leaf-eating caterpillars, mirids, and bark-scraping beetles, are some of the insects which initially attack the newly-planted seedlings or regenerated chupons. Other insects of less importance known to attack such farms include thrips, termites, aphids and psylids. The Psylids and aphids attack the young flushes, while thrips are found mostly on mature leaves. Most of these insects can be controlled by spraying with Gammalin 20. For foliar application, the concentration should be 4-8 oz. active ingredient per acre in 20 to 40 gallons of water. Mirids can be controlled by spraying 1/5th of a pint of the formulated material in two gallons of water, for every forty trees. Leaf-eating caterpillars is 3-10 oz. a.i per acre in 20 to 40 gallons of water. The frequency of spraying will depend upon the severity of attack. It is undesirable to spray with Rogor when the trees begin to bear fruit.

All instars of *Zonocerus* variegatus can be killed easily by the common insecticides (Fenitrothion) using solutions of 0.1% wt/vol. a.i. The best time for spraying is in the early mornings or late afternoons when the insects are less active and preferably on the highly aggregated early instars of the insect. However, due to the well dispersal and highly 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. The red-banded thrips, Selenothrips rubrocictus could be effectively controlled on cocoa by spraying fenitrothion or pirimiphos-methyl onto the undersurface of the leaves. A threshold of 35-100 egg masses per hectare or 1 larva for every two plants has been suggested for control of Spodoptera littoralis. 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). Dichrotophos and Monocrotophos were found to be effective for the control of the spiny bollworm, Earis biplaga in cocoa, while Dioxocarb was recommended for the cocoa shield bug, Bathycoelia thalasssina, Endosulfan, Cypermethrin, Lambda-cyhalothrin and Fenitrothion have been suggested for effective control of larvae of Spodoptera littoralis. Also, Chloropyrifos, Dimethoate, Fenitrothion and Triazophos effectively controlled Helopeltis schoutedeni. Dichrotophos and Fentrothion were found to be effective for the control of the leaf roller, Sylepta spp, the defoliator, Anomis Leona and the caterpillars of Anaphe venata in kola, while Dioxocarb was recommended for the kola pod borer, Characoma stictigrapta. Effective control was achieved with these insecticides by spraying them onto the undersurface of the leaves and immature pods. Termites could effectively be controlled by the application of insecticides (Methidathion, Carbofuran, Endosulfan, Pyrinex, Dursban, Termicid, Endocap and Fenitrothion) to the soil around the base of the cocoa seedlings and mature plants just before the outset of the dry season.

Many scientists have carried different chemical control trials against the kola weevils. These include; fumigation of the nuts with phostoxin; dipping of weevil-infested nuts in concentration of 0.03% gamma BHC emulsion and irradiation of kolanuts using gamma radiation generated from cobalt 60. It is worthy to note that irrespective of all these trials, there has been no categorical recommendation of chemical control of kola weevils. This is due to the fact that kolanuts need no further processing before consumption hence no level of chemical residue on it will be acceptable. 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 involved spraying thrice a year in January, October, November with 0.05% Dimethoate or Rogor. 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 cottonstainers, Dysdercus superstitiosus could effectively be controlled by the use of Endosulfan, Pirimiphos-methyl, Lambdacyhalothrin and Fenitrothion. The use of insecticides possesses a great threat to man and the environment and therefore calls for a more concerted effort for the exploration and introduction of a more human and environmentally friendly method of pest control.

Pesticides considered safe for protection of tree crops

The following synthetic insecticides such as Actara 25 WG, Esiom 150 SL, Proteus 170 0-TEC, Avesthrin, Termicid, Capsida, Phostoxin, Zap, Confidor etc. were screened against attacks of kola/Cocoa weevils/mirids. This is to determine biodegradability of the insecticides with little or no residue effect that may pollute the environment Asogwa [28]. Among the chemical insecticides screened, Actara 25 WG, Esiom 150 SL and Proteus 170 0-TEC passed through all the stages and considered effective and thus recommended for use on Kola/Cocoa tree or their products. However, Phostoxin is recommended as a fumigant in controlling storage pests. Other chemicals aside recommended ones are still under investigation Asogwa [28]. Though there is need to check or monitor the influx of banned or adulterated insecticides in the country, equally enlighten farmers/traders on the use of currently approved insecticides and involved modern techniques Asogwa [28].

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Use of natural plant products (Botanicals)

Due to the hazard effects of synthetic chemicals there is an urgent need to develop an alternative form of pest control that is non-toxic, biodegradable and affordable for the management of pests of agriculture and public health. This will help to protect the environment and reduce the economic and social costs of agricultural production. Crude extracts from selected plant species and other materials of biological origin appear to offer an effective method of pest control especially when used within an integrated pest management schedule. Plant extracts can provide a simple means of control that can be used by farmers. Botanical protectants have a great deal of advantage over all other types of protectants. This is because they do not lead to the buildup of resistance by insect pests. Most of these botanicals are acquired freely in the environment. They do not pose health hazard to the local farmers, as most of them are either medicinal plants or vegetables that are consumed as food. It also can help in rural development and employment for the rural populace through the establishment of cottage industries for the processing of selected plant materials for pest control. The natural pesticides from these plants may be utilized in the form of powdery, oil or aqueous formulations and could be applied in various ways ranging from the broom sprinkling method to the use of knapsack sprayer.

Legislative control (Quarantine)

This involves the regulation of plant materials from one region to another in order to restrict the introduction of exotic pests, which may be accidentally transported by those plant materials. The government of each country or region enforces this law (Quarantine laws), which are prohibitive at all ports of entry into a given country. The law requires all imported plant materials to be brought in with an import permit accompanied by a phytosanitory certificate, which guarantees the state of health of imported materials. Regulatory control also prevents the spread of pests from one location to a wider area in a given zone.

Integrated pest management (IPM)

Integrated pest management (IPM) is process consisting of the balanced use of cultural, biological and chemical procedures that are environmentally feasible and socially acceptable to reduce pest populations to tolerable levels. It could also be defined as a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks. Integrated pest management (IPM) involves the judicious utilization of two or more of the control methods to achieve a more effective control. For instance strict cultural practices can be used effectively with minimal pesticide sprays to get rid of most devastating stages of insect pests. IPM approach discourages the use of persistent pesticides (Organochlorine and organophosphates), rather Carbamates, Pyrethroids, Natural plant products (Botanicals) and Bio-insecticides (formulation based on pest pathogenic microbes) are now being favoured for use on agricultural products. For almost two decades (1970-1990) research efforts on pests and diseases of cocoa were concentrated on bioecology and control of cocoa mirids, black pod disease and cocoa swollen shoot virus disease. By late eighties it had become obvious that most of the recommendation extended to cocoa farmers on the control of these insect pests and diseases have become inadequate and unsustainable. This was because mirids have developed resistance to all lindane-based insecticides that are widely used by farmers. These insecticides together with the copper base fungicides recommended for the control of black pod disease also became expensive and less affordable. Hence, the need to identify alternative but sustainable techniques for the management of these pests and diseases. In view of the above scenario, concerted research efforts were made to identify and evaluate various control techniques (Cultural, biological and chemical), which could be harnessed for integrated management of these most important pests and diseases in Nigeria.

Conclusion

The knowledge of ecology combined with life cycles of insect pest would enhance better understanding of the best option of pest management strategies to employ. Therefore, the sparingly use of chemical (0.025 ml) with other control options in a compatible manner would achieve effective and sustainable pest management. Some chemicals have been banned but the information is yet to reach those who buy in ignorance and apply without knowledge. In the foregoing, the approved and prohibited pesticides are provided to make producers to take right decision. Accredited sources in Nigeria have been provided so that fake chemicals are avoided and recognized Asogwa [28]. Some of these chemicals must be used at specific times and locations in the value chain of the crop. Consequently, it is important to use the right chemicals so that the quality of the farm products would not be affected when used for food items Asogwa and Dongo [29]. It is worthy to note that irrespective of previous storage trials, there has been no categorical recommendation of chemical control of kola weevils [30-50]. This is due to the fact that kola nuts need no further processing before consumption hence no level of chemical residue on it will be acceptable [50-74].

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