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Studies of the Ant-plant Mutualism in the Nigerian Cocoa Agroecology

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Abstract: The studies on ant-plant mutualism spanned from field observations of myrmecophytic associations as well as survey of various ant species found in a 2-ha cocoa plantation to laboratory experiments on predation of cocoa mirids by ants. *O. longinoda* was the most pugnacious ant species encountered in the field and it gave a 100% predation of its prey in the laboratory. All the other ant species exhibited some degree of predation and this invariably portends ants as natural enemies of the most important insect pest of cocoa. Predation was not effective in the field because these ants were primarily tending coccoids. As an agent of pollination, this was not substantiated, as there were no traces of pollen grains on the body parts of ants as well as lack of ant parts from flowers teased in the laboratory. However, frequent visits of two genera of ants, *Cremastogaster* and *Camponotus* to flowers were noticed in the field.

Key words: Myrmecophyte · survey · ants · cocoa · natural enemy · pollination

INTRODUCTION

Various ant species have been encountered in cocoa farms in Nigeria but not much has been done to study the mutualistic interactions among cocoa, pests of cocoa and these ants [1]. Reports exist of some other plants in which the relationship reaches a high degree of sophistication in the so-called myrmecophytes (ant-plants). The plants offer housing and food for their ant partners and in return, the ants are known or presumed to protect the plants from herbivory. Additional benefits to the plant may include protection against pathogenic fungi, removal of vines, nutrient addition through breakdown of collected debris in domiciles and absorption of ant-respired carbondioxide [2, 3].

Many plant species only establish comparatively weak, unspecific relationships with ants by providing food (e.g. extrafloral nectar) for ant visitors but no nesting space. This is particularly true of *Crematogaster* ants that are more numerous in the vicinity of plants with extra-floral nectaries [1].

Actually the term 'myrmecophyte' could describe plants regularly inhabited by ants, without implying that the host plants actually benefit from the ant tenants. It could also mean plants species that have evolved specialized structures (domatia) that house ants. The term is also used for plants that are nevertheless regularly inhabited by one or more plant-ant species, in the absence of known specialized structures [4].

In the Nigerian cocoa plantations, a lot of associations have been observed over the years. For example, *Crematogaster* species have been implicated to be a significant part of the ant-mealybug-cocoa virus association because it is the main species tending mealybugs on established cocoa whereas *Pheidole megacephala* is the main mealybug tenders on seedling and young cocoa [1]. Ants, which cover Homoptera with carton tents such as *Crematogaster* and those that fold Homoptera within their nests (e.g. *Oecophylla longinoda)* preserve them against adverse seasonal effects and so ensure for themselves a continous supply of food. Large workers of *O. longinoda* are predatory and trees colonized by them carry very few other insects [1].

It is against this backdrop that this investigation was carried out to ascertain the ant biodiversity found in the Nigerian amazonian cocoa plantation as well as investigate the specific mutual associations that exist between these ant species and their host plant, cacao.

MATERIALS AND METHODS

Study Site: This study was carried out at the Cocoa Research Institute of Nigeria (CRIN) Headquarters in Idi-Ayunre, Ibadan, Nigeria. Ibadan has an annual rainfall

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average of 2000mm with a bimodal pattern and Idi-Ayunre is located in the tropical humid rainforest ecosystem. It lies between the latitude 7°30′ N and longitude 3°54′E at an altitude of 200m above sea level.

Survey of Ants species: Sampling of ant species was conducted on a monthly basis from February 2005 to May 2006 on a two hectare plot of cocoa planted at a spacing of 3.1 by 3.1 m spacing in absolute monoculture in 2000. There were no shade trees at all in the plot as these have been felled in year 2000 when the cocoa seedlings were being established and plantains that served as temporary shade have been eliminated following the full establishment of cocoa. Each cocoa plant was closely observed for ant species around the trunks, branches, flower cushions, flowers, leaves, chupons, pods and cherelles and soils around the bases of plants. Collection of ants was done with the aid of camel hairbrushes. Ants were brushed into 2lb sized kilner jars containing cotton wool covered with filter paper and soaked in ethyl acetate while a few numbers were placed in containers without ethyl acetate for further experimental work in the laboratory. Ants species found were later identified in the Insect Museum of CRIN and those that could not be identified in CRIN were taken to the University of Ibadan Insect Museum in the Department of Crop Protection and Environmental Biology, Ibadan. Ant nests were also collected and the occurrence of other insect species was observed on trees having ants. Various aspects of the ant-plant associations were observed in the field, including myrmecophytic characteristics (e.g. occurrence of extrafloral nectarines, food bodies, or domatia) and the specificity of the relationships between the cocoa plant and its ant inhabitants, as well as the occurrence of trophobiotic homopterans (Scale insects, mealybugs).

Predation experiment in the laboratory: Predation experiment was set up to investigate ant species as natural enemies of certain insect pests such as mirids that are well known to be inimical to cocoa production across West Africa. Field-collected ant species were separately introduced into transparent plastic cylindrical containers with dimensions of 15cm by 18cm (Height x Diameter). These containers were lined at the base with tissue paper to avoid condensation and a pod containing one field-collected mirid was placed inside each container. The pods were left for the duration of the observation. Five ants of the same species were thereafter introduced separately into each of these containers and replicated at least five times. The containers were covered with their plastic lids that have a portion of 14cm by 12cm (Length x Breadth) made of muslin to allow for aeration and placed on a platform inside the Entomology laboratory for observation. A control experiment was also set-up and this time without any of the ant species. The temperature and relative humidity were maintained at ambient levels of 26±2°C and 70-80%, respectively. The set-up was monitored and observed at two hourly intervals for a period of 5 days.

Collection of cocoa flowers and ants found around the flowers: In order to ascertain the role of ants as possible agents of pollination in cacao, ant species found around and inside flowers were carefully collected using a camel hair brush and the ants were knocked off in kilner jars with ethyl acetate soaked cotton wool. Flowers from which ants were found were plucked and put inside a separate container. Both flowers and ant specimens were later taken into the laboratory for further observations for ants/ants parts and pollen grains, respectively. Teasing of flowers was done in 75% ethanol and observed under a binocular microscope.

RESULTS

Field observations and survey: Only seven ant types were identified from the survey of ant species found in a 2-ha cocoa plot. The seven ant types were *Oecophylla longinoda, Crematogaster brevispinosa, Camponotus acvapimensis, Camponotus zoc*, *Acantholepis capensis, Camponotus flavomarginatus and Palothyreus tarsatus* arranged in decreasing order of number in collections made (Table 1). Table 1 presents the summary of ant species, their nesting behaviour and associated coccoids in cocoa plot in Nigeria. All seven species were attracted to secretions by coccoids (honey dew) on pods infested with mealybugs. Cocoa trees infested by ants have from very few to no other insects on such trees. Fewer mirid damage symptoms such as lesions on pods were found on trees with ant species whereas on trees inhabited by the tailor ants, *O. longinoda,* there were no symptoms of pod damage by mirids and none of the insect pests of cocoa was found on such trees.

O. longinoda built many small nests averaging 24 per tree by binding adjacent living leaves together with a silk-like material produced by the younger larvae. These larvae were held in place by the workers who weave them backwards and forwards against the edges of leaves to be

Table 1: Occurrence of ant species, their nesting behaviour and associated coccoids in cocoa plot in Nigeria

Ant species	Nesting behaviour	Number of collected		Nests per tree	Associated coccoids
		Ants	Nests		
Crematogaster brevispinosa	Carton-structured nests attached to main stems and trunks	128	12	2.0	*Planococcus citri*
Camponotus flavomarginatus	Soil-nesting at the base of trunks of mature tree	48	2	-	*Planococcus citri oxoptera aurantii*
Camponotus zoc	Arboreal nests on dead branches of tree	62	6	1.0	*Planococcus citri Toxoptera aurantii*
Camponotus acvapimensis	Nests on dead tree branches	93	6	1.5	*Planococcus citri*
Acantholepis capensis	Soil-nesting near the base of tree	56	1	-	*Planococcus citri*
Palothyreus tarsatus	Nested under felled dead wood in the plot	22	1	-	Planococcus citri
Oecophylla longinoda	Arboreal nests formed by binding together adjacent living leaves of cocoa	256	78	24.0	*Planococcus citri Stictococcus sp.*

Table 2: Predation of the cocoa mirid, *S. singularis* by ant species in laboratory cages

Ant species	Mortality of mirid (%)				
	1	2	3	4	5 (DAT)
Oecophylla longinoda	75.5	80	100.0	100.0	100.0
Crematogaster brevispinosa	0	0	10.5	10.5	10.5
Camponotus acvapimensis	0	15	30.0	35.0	35.0
Camponotus zoc	0	10	10.0	15.5	15.5
Camponotus flavomarginatus	15	15	20.3	20.3	20.3
Acantholepis capensis	30.8	45	45.0	50.5	50.5
Palothyreus tarsatus	0	20	30.8	30.8	30.8
Control	0	0	0.0	0.0	0

DAIM = Days After Treatment

joined [1]. It is believed that this habit earned the ant the name tailor or weaver ant. *O. longinoda* was more predominant than any of the other ant species surveyed. *O. longinoda* appeared to be very aggressive when disturbed and always showed a peculiar 'alarm dance' to alert other members of the colony of the presence of an intruder and during this period cocoa leaves vibrated for about 50 – 60 seconds. They were attracted to evergreen cocoa trees, so that nest materials could be available all the year round. 259 tailor ant collections were made out the whole lot during the sampling period. The ant was the most abundant.

C. brevispinosa had brown carton nests measuring 6.0 x 4.5 x 2.5 cm on the average. The nests were formed as carton structures attached to the outside of trunks, main stems and branch unions. A total of 128 ants were collected and 12 nests were found.

Three species of the *Camponotus* genus were identified which differ in their pattern of nesting. While *C. flavomarginnatus* nested in the soil around the base of cocoa trunks, *C. acvapimensis* and *C. zoc* has an arboreal nesting behaviour in which their nests were found on dead parts of branches in cocoa trees. They were exclusively tending the mealybug, *Planococcus citri* and the cocoa aphid, *Toxoptera aurantii*.

Only one nest of *A. capensis* was found and the activities of this species were rather sporadic and were actively involved in attending to coccoids on cocoa pods. Subterranean nests of soil nesting ants were usually difficult to locate.

P. tarsatus was the least abundant and members of this species were found individually on the cocoa trunks. The nest was found under a dry dead wood in the cocoa plot. *P. tarsatus* also tends coccoids.

Natural enemies and pollination studies: The predation exercise carried out in the laboratory showed *O. longinoda* to be the best natural enemy of the brown cocoa mirid, *Salbergella singularis* as mean mortalities of 80% and 100% were recorded 24 and 48 hours after introduction of the ants respectively, (Table 2). The tailor ants devoured and ate up all the mirids and no remains were left. *A. capensis* gave 50.5% kill of the mirids at the end of 5 days while *C. acvapimensis* gave 35% predation within the same period. All the ant species exhibited some degrees of predation on mirids in the cage. Mirids in the control set-up without ants were all intact at the end of the 5th day.

Many others yet to be identified ant species were collected from and around cocoa flowers, which upon close observation with a hand lens did not reveal the presence of pollen grains on any of their body parts. However, these ants were observed to be moving up and down the trunks of cocoa bearing flowers buds, cushions and opened flowers from which they were collected. Teased flower parts in ethanol, observed under a binocular microscope did not contain any insects or body parts of insects.

DISCUSSION

Results obtained during the survey of ants within the 2-ha cocoa farm only gave an estimation of abundance of the various ant species as getting the actual number of ants was rather difficult coupled with the fact that the nests of some species especially the soil nesting ones were difficult to find. All the ants sampled were coccoidophillic and did not carry out any damage on cocoa. In addition, cocoa trees with ant occupation had little or no presence of economic insect pests of cocoa and this is particularly true of the tailor ant, *O. longinoda.* The predatory activities of *O. longinoda* as observed from the field and laboratory experiments consequently present this species as the best natural enemy of mirid pest of cocoa and invariably protect the cocoa plant from insect pest herbivory. The brown cocoa mirid, *S. singularis* is the most economic insect pest of cocoa capable of reducing the yield of cocoa by up to 30% [5]. Entwistle [1] observed that *O. longinoda* is pugnaciously active and has a characteristic nesting habit of joining living leaves on trees inhabited. This result is in consonance with the report of Letourneau [6] who discovered a similar phenomenon in *Piper* ant-plant, in which ants increased plant fitness by reducing the loss of photosynthetic area or plant injury due to herbivore exploitation. Khoo and Ho, [7] reported that early this century cocoa planters in Indonesia observed that the presence of a species of ant, *Dolichoderus thoracicus*, was associated with greatly reduced damage caused by mirids, an important group of pests attacking cocoa. Ants' species, especially *O. longinoda* could be explored as a biological control agent for the control of mirids. However, inspite of this excellent result of predation achieved in the laboratory, these ants may not be able to achieve this feat in the field because of their ranging mode of life and especially their primary course of tending and attending to coccoids in order to exploit their honeydew which is the main stay of the ants' economy/livelihood. This is a major limitation.

Another aspect of ant mutualism in cocoa could be in the area of pollination. Insect of the family Ceratopogonidae, the midges especially of the genus *Forcipomyia* is reported to be responsible for pollination in cocoa flowers [1]. Field observations however revealed frequent visits of ants to and from the cocoa flowers, most especially ants belonging to the genera *Camponotus* and *Crematogaster.* Posnette [8] found ants of the *Crematogaster species* to be important pollinators of cocoa in Ghana while Idowu [5] reported that Ceratopogonid midges were mainly involved in pollination of cocoa flowers as well as other minor pollinators such as ants, psyllids, aphids and bees.

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