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Habitat adaptation and population of nymphal and adult stages of two cocoa mirid species (D*istantiella theobroma* [Dist.] and *Sahlbergella singularis* Hagl.)

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Abstract

This paper describes part of a detailed study of the habitat and feeding-site adaptation and population of different life stages of two important cocoa mirid species, *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hagl. (Hemiptera: Miridae). The study was conducted from 1981 to 2015 in the Eastern Region of Ghana (6.24.676 N, 0.52.074 W). The insects have low population densities, but strong environmental and habitat adaptability. They easily reach damaging population levels when environmental conditions are suitable. In field studies across a block of 8 ha plot in 34 years, 17,892 *D. theobroma* and 31,143 *S. singularis* in total were sampled with significant variability in dominance detected in habitat affinity between the two species. Nymphs were the most frequently detected stage (93.2%), and significant differences in abundance were detected in habitat preference. The old perception that *D. theobroma* had strong habitat affinity for pods than *S. singularis* could not be established in the present study. In contrast, 63.3% *S. singularis* and 54.7% *D. theobroma* were recorded on pods. Of all the samples collected on pods, green unhardened tissue (chupons), fan branches and trunks, mirids were present in the following order; pods (60.1%) > chupons (30.8%) > fan branches (5.1%) > trunks (4.0%). The widespread occurrence of *S. singularis* on different tissues reflects their broad habitat affinity and environmental range. Mirid numbers decreased with decreasing moisture and rising temperature. Peak populations occurred in January to March and August to December, but the two species were most abundant in September. The consistent low field observations of *D. theobroma* suggest that newer cocoa varieties are likely to contribute substantially to *D. theobroma* suppression, at least during the time period of the study when newer insecticide formulations were being widely applied nation-wide for mirid control. For *S. singularis* that were relatively well represented across different parts of the plants, conventional insecticide application which is the main method of control may be fruitful when application is purposefully targeted at the pods and chupons.

Key words: cocoa, mirids, population, habitat preference

Introduction

Cocoa (*Theobroma cacao* L.) is a tropical cash crop and the primary source of income for over 10 million people (Baah and Garfoth, 2008). It is a long-life tree crop with high market value and cultivation is limited to fertile forest lands. In West Africa, cocoa is largely grown by small-holder farmers of limited resources (Adu-Acheampong *et al*., 2017).

Mirids (Hemiptera: Miridae) are tropical plant bugs, and *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hagl. are the two most important species that are considered as cocoa pests, and which cause serious problems in all cocoa growing areas of West and Central Africa. Other mirid species such as *Helopeltis bergrothii* and *Bryocoropsis laticollis* are less important pests of cocoa because they produce little direct economic effects. On cocoa, they feed on pods, chupons and newest growths on fan branches. During feeding, mirids inject enzyme-rich saliva into plant tissue and suck plant juice from conducting tissues. Plant damage symptoms characteristic of mirid attack are lesions on pods and stem, and cherelle wilt. Severe infestations cause plant death in trees less than one year old or delay in the time to pod production. (Entwistle, 1972).

Distantiella theobroma was first reported by Dungeon in 1908 from farmers' cocoa farms in the Eastern Region of Ghana (Dungeon, 1910). For over a century, the insects have remained major pests of cocoa throughout the cocoa growing regions of Ghana. Yield losses due to mirids are severe and individual plant losses of newly established cocoa farms can be as high as 70%. Under heavy infestation of mature cocoa farms, dry cocoa beans can be reduced by as much as 30% (Stapley and Hammond, 1957, Collingwood and Marchart, 1971). In the early years, mirids severely affected cocoa cultivation to the extent that producers in some parts of the country no longer grow cocoa, but have shifted to other crops such as oil palm.

Attack by mirids is reduced by applying insecticides (Owusu-Manu, 19990; Adu-Acheampong *et al*., 2014), and use of cultural methods such as chupon removal and shade management. A major challenge to effective pest control is ensuring that pesticides reach the target pests while protecting beneficial organisms that provide important ecosystem services such as those acting as pollinators and natural enemies. Moreover, mirids living and feeding behind pods and in pod unions are little affected by poor insecticide applications methods. This challenge is particularly relevant to cocoa farmers who require efficient pest control to achieve economic yields. An important part of effective pest and disease control with chemical sprays is correctly timing the application and hitting the right target. This requires an understanding of both the pest that is to be controlled, and the place where the sprayed product must be deposited in order to work on the pest.

In the cocoa agro-ecosystem of West and Central Africa, temperature, soil moisture and relative humidity are probably the most important environmental factors affecting plant growth and insect establishment. Chupon growth and pod set are enhanced through morphological and physiological adaptations to the humid environment and these sites tend to have higher population than on other parts of the plant. Damage assessment of pests under field conditions indicate how mirids adapt to different plant parts in different times of the year. Besides food and shelter, it is not clear which factors influence plant part selection by insects. This is especially true for cocoa mirids which spend their entire lifetime on the stem and pods. Attacks by mirids are frequently associated with increased vigour of the trees caused primarily by favourable climatic factors. One of these factors which have been associated with severe mirid attack is adequate rainfall. Adu-Acheampong *et al.* (2014) also recognized that attacks by mirids were connected with host vigour. Mirids are patchily distributed in the field. The insects frequently concentrate their attacks on a few trees (mirid pockets) rather than infest a large number of trees. Females with their ovipositor create minute holes in green unhardened tissues into which eggs are singly deposited leaving a pair of fine respiratory vents. After the nymphs are hatched, they move away from the egg galleries and feed on the fresh, unhardened parts of the stem and pods creating what is termed mirid pockets – localized areas of infestation. When the nymphs have transformed into adults, the young bugs continue to feed on the stem and pods for a short time and then fly away to attack other trees. A more detailed account of the biology of the species is given by Raw (1959). As the plant grows, selection of different plant parts as sources of food occurs.

As in many parts of West Africa, mirids in Ghana apparently continue to breed throughout the year producing some 8 to 9 generation in the year. In Ghana, a much higher frequency of mirid damage on cocoa was attributed to lack of natural enemies and the inability of a cocoa tree to tolerate a few mirids per plant without economic harm (Adu-Acheampong *et al*., 2014). Subsequently, insecticide application is the most common and effective method used to control mirids on cocoa.

The degree of usage by mirids of different organs as habitats – (feeding sites) has been little published and critical evaluation is needed to determine which of the different organs serve as important feeding sites. Therefore, in this study different plant parts (pods, green unhardened tissues – [chupons] and fan branches were sampled for occurrence of different life stages of mirids. Identification and categorization of feeding site preferences is a prerequisite for developing targeted insecticide application methods for mirids on cocoa. This information will also aid existing integrated pest management efforts at mirid control.

Materials and methods

Site description

The research was conducted on farmers' farms located at Pankese (N 6.24º.6 W 0.52.0º) in the Eastern Region where mirids, *D. theobroma* and *S. singularis* have consistently been abundant. This is also the main site where small-scale insecticide trials are conducted, and where mirid resistance to lindane was first recorded in 1963 (Dunn, 1963). The mean annual rainfall of over 1200 mm is bimodally distributed, March-July and September-November, with the maxima in June and September or October. The annual average temperature is about 31 ºC. The climatic data (temperature, rainfall and relative humidity) during the sampling period were obtained from records at the Cocoa Research Institute of Ghana (CRIG) Weather Station at Afosu located about 20 km away from the study site.

Abundance, temporal distribution and habitat adaptation of mirids on cocoa trees

The study was conducted during 1981 to 2015 in mature cocoa farms planted with mixed hybrid cocoa in the Sampling plots comprises four 0.4-ha plots selected over a block of 8 ha. The periodicity of sampling was one month intervals. The location of mirids on cocoa trees was monitored throughout the year by visual sampling on all trees within the plot (400-500 trees), and mirids were classified according to the development stage of the insect: as nymphs and adults. Habitat and feeding site preferences were estimated for both *D. theobroma* and *S. singularis.* The sampling method has previously been used by the International Capsid Research Team (Collinwood, 1971, Adu-Acheampong *et al.,* 2014). No data was available for 1983 because of the severe drought and bush fires that swept across the entire country.

Statistical Analysis

An X^2 goodness of fit test was used to test for divergence from the expected uniform distribution of the relative abundance of mirid life stages among four different feeding sites.

Results and discussion

Site of the cocoa tree used by mirids for feeding

In field studies across a block of 8 ha plot in 34 years, 17,892 *D. theobroma* and 31,143 *S. singularis* in total were sampled with significant variability in dominance detected in habitat affinity between the two species. This represents a 1.74-fold dominance of *S. singularis* compared with *D. theobroma*. The temporal distribution of nymphs and adults sampled each month from 1981 to 2015 are shown in Figs. 1 and 2). Nymphs were the most frequently detected stage (93.2%), and significant differences in abundance were detected in habitat preference. It was found that most of the organs of the trees pods, chupons, fan branches and trunks are frequented but with markedly different frequencies as can be seen in Figs 1 and 2. Mirid population started to increase in July, peaked in September, and the decreased in December. A second peak occurs in the first quarter of the year.

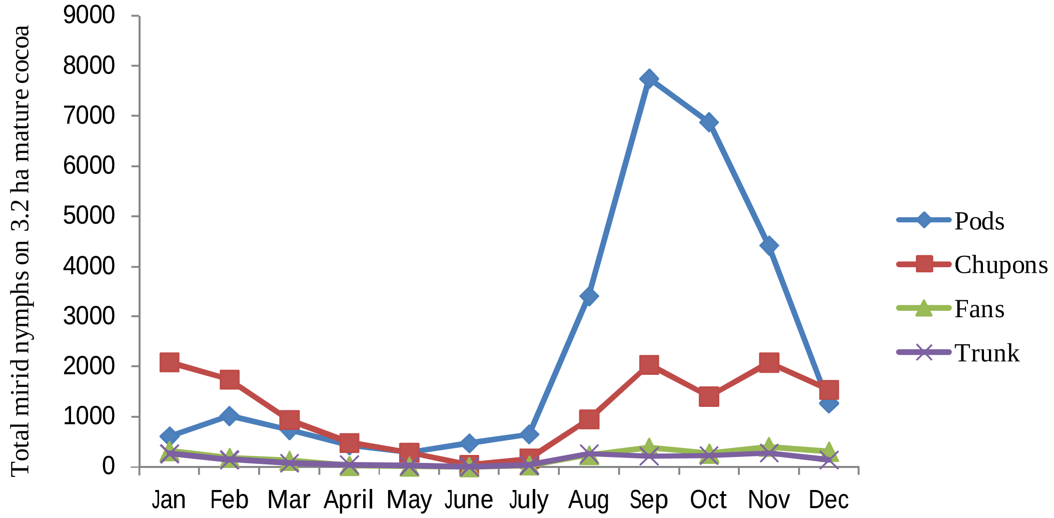

Fig. 1. Seasonal abundance of mirid nymphs on different plant organs

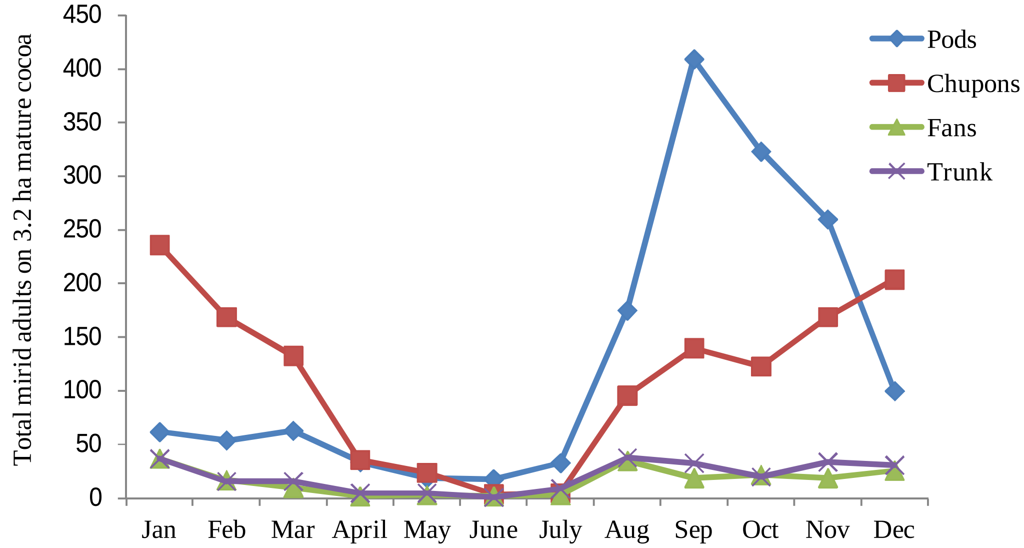

Fig. 2. Seasonal abundance of adult mirids on different plant organs

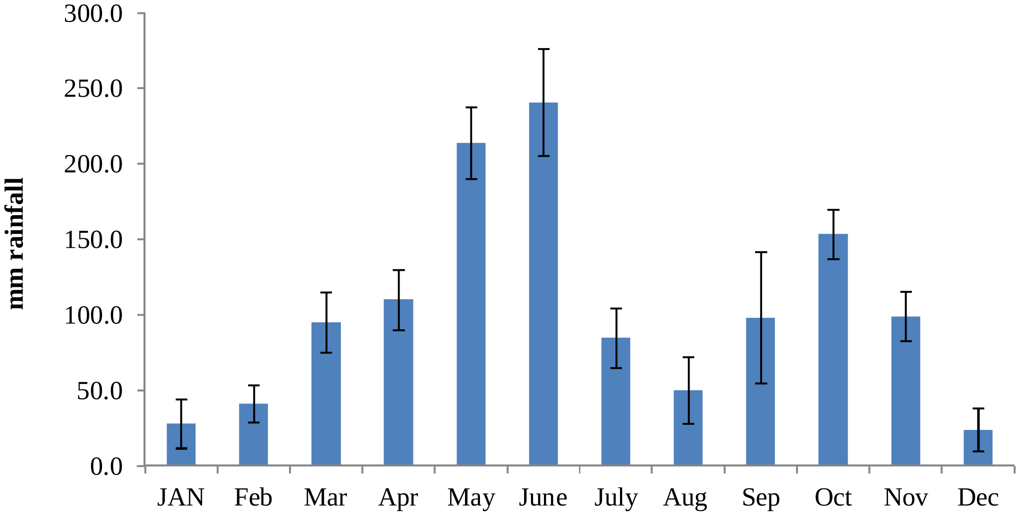

Fig. 3. Mean monthly rainfall for 2012-2015

Field observations in the present study have shown comparable differences in incidence of mirid adults and nymphs on cocoa trees. This indicates a clear prevalence of nymphal stages and a more similarity between the patterns for the two mirid species, *D. theobroma* and *S. singularis*. Thus, more nymphal stages were sampled and only a few adults were found throughout the study period. The presence on the different plant organs was similar for nymphs and adults. The results showed also that the pod is the most desirable site on the cocoa plant which attracts mirids.

Adults were irregularly present on the pods with peak for *S. singularis* and *D. theobroma* in September and October, respectively. The woody stems were also used as refuge throughout the season but were particularly important between August and November. Regarding the woody part of the plant as shelter or site for feeding, *D. theobroma* and *S. singularis* were present in variable numbers, but more mirids were generally sampled on the fan branches than on the trunk except in August when *D. theobroma* was abnormally higher on the trunk.

Since the first reported case of mirids as serious pests of cocoa in Ghana in 1908, damage by the pest to the crop has remained high even after the introduction of improved planting materials. Results from the present study showed that the season of major mirid activity is from August to April and pods and chupons were the preferred sites by all life stages. Between-species habitat affinity was not significant between *D. theobroma* and *S. singularis*. Overall, *S. singularis* was more abundant than *D. theobroma*. The previously held view that *S. singularis* preferred more matured woody tissue that *D. theobroma* could not be confirmed in the present study.

Life cycle studies suggest that there could be 8-9 generations of the pest in a year. High temperatures and low relative humidity lead to almost no activity of adults on fan branches and pods during May to somewhere July, and it is thought that those insects which develop on chupons and pods which perpetuate the cycle of the next generations. Mating and hatching of eggs laid by early season females under good climatic conditions in June and July perhaps gave rise to the first peak in September. In Ghana, the peak pod harvesting occurs during November and December and this may be responsible for the decreasing number of mirids that remained low until February and March when another peak occurred. This second peak may have been induced by the simultaneous hatching of eggs laid by an earlier overlapping generation and probably the enhanced quality of sap caused by nutrient retranslocation during leaf senescence caused by drought (Soudry *et al.*, 2005).

It is deduced that the highly mobile nymphs move along the plant, mainly the trunk. Most reach the pods and chupons and remain under the pod stalks or behind the pods where temperatures and relative humidity are optimum for growth and development. Field observations show that mirids presser concealed places under the pods and in cracks under the back and in branch unions rather than the exposed parts of the shoots and the pods. (Entwistle, 1972). Thus, the study showed that mirids insects are rarely found on the cocoa leaves. In the present study, relative humidity appeared to be an important variable in terms of the population dynamics of mirids. Entwistle (1972) hypothesized in previous literature that rainfall and the subsequent increase in humidity are highly linked to pest population explosion in cocoa. From the foregoing, chupon removal and directing insecticide sprays at chupons and pods, can improve deposits of insecticides and efficiency of pest control in cocoa. These measures would be particularly important in periods when mirid numbers are high during February –March and August to December.

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