

Future strategies towards control of mirid (Hemiptera: Miridae) and common insect pests of cocoa (*Theobroma cacao* L.) in Ghana

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Abstract

Changing farming systems in cocoa over the last two decades has brought about the use of new hybrid plant varieties and intensified fertilizer and pesticide applications have increased the importance of insect pests on cocoa. Historically, the major management tool for hemipteran pests has been calendar spraying with conventional insecticides. Considerable progress was made at the turn of the last century by replacing organochlorine insecticides for cocoa mirid control, but inadequate timing and inefficient application is probably reducing the viability of otherwise acceptable products. The future Integrated Pest Management (IPM) strategy for mirid and other insect control should be based primarily on the use of cultural practices of removal of excess chupons, shade management and host variety resistance. These practices are primarily aimed at minimising dieback disease and stink bug deformation of pods, and may then be supplemented in some cases by the use of insecticides (up to two applications in February to May at 28-days intervals) depending on the pest populations, damage levels as well as intensity of activity of pollinating insects, with additional two applications in September to December when pest problems may arise. Improved methods of monitoring and prediction should assist in early identification of specific problems in different farms. The rotational use of different active ingredients should also take into account factors such as application methods, compatibility and correct timing. Careful planning is necessary to formulate a flexible control system.

Key words: mirid, pest control, cocoa, farming systems, control strategy, correct timing, dieback disease, insect pest, flexible control system

Running title: Strategy for pest control in cocoa

31 Introduction

32 Mirids (*Distantiella theobroma* [Dist.] and *Sahlbergella singularis* Hagl.) and stink bugs
33 (*Bathycoelia thalassina* (Herrich-Schaeffer)) are known for their importance in causing losses
34 in cocoa (*Theobroma cacao* L.) in West Africa (Johnson, 1971, Entwistle, 1972, Owusu-
35 Manu, 1976 and Adu-Acheampong *et al.* (2012), with the most prevalent in Ghana being *S.*
36 *singularis*. The authors have outlined the problems associated with mirid and stink bug
37 infestation. Both nymphal and adult stages feed and inject saliva to liquefy plant tissues.
38 Their feeding punctures provide entry points for fungal pathogens (Crowdy (1947), Owen
39 (1956), McGhee (1997), McPherson and McPherson (2000). This secondary invasion of
40 mirid feeding punctures causes dieback disease whilst that by stink bugs results in premature
41 ripening and deformation of pods and beans. The main method of mirid control is by the
42 application of conventional insecticides, but stink bugs have often been controlled indirectly
43 by treatments normally used for the control of mirids.

44 In Ghana, new pests have emerged and their control is difficult compared with three decades
45 ago (Owusu-Manu, 2001). There are several contributory reasons for this: farmers still have
46 to be familiarized with optimal techniques of using the new generation insecticides that have
47 largely displaced the organochlorine and carbamate compounds. The global quality standards
48 of insect pest control in cocoa needed to guarantee high quality produce for global market
49 outlets have increased, setting targets for maximum residue limits of pesticides, which in
50 some instances are clearly not attainable.

51 A fast and correct diagnosis of pest incidence is the first important step in attempting any
52 control procedure. Adu-Acheampong *et al.* (2014) have concluded that pest control systems
53 in cocoa must be revised as a result of changes in farming systems, pest cycles and shifts in
54 pest population peaks.

55 Before discussing the strategy for mirid control in cocoa in Ghana it would be useful to
56 examine the history of this insect's control.

57 Before the 1970s damage caused by mirids was well appreciated as well as the importance of
58 dieback disease that follows mirid feeding on green unhardened tissue (pods and stem).
59 Efforts were concentrated on understanding population fluctuations of mirids on different
60 varieties of cocoa, their distribution within trees as well as the effect of water stress on the
61 incidence of pests. The tendency for average population levels to remain low until a sharp

62 rise in August or September was the basis for the establishment of the calendar spray regime
63 beginning in August until December (but omitting November) (Stapley and Hammond, 1957)
64 This was to replace an older recommendation of June, July followed by a three-month gap
65 (Peterson and Bond, 1964). Currently, two seasonal peaks varying from September-
66 December and February-May in different locations is an average phenomenon. Plant
67 breeders at the Cocoa Research Institute of Ghana (CRIG) have developed varieties of cocoa
68 resistant to swollen shoot and black pod which are also high yielding but unfortunately this
69 resistance does not seem to be durable enough when the varieties are challenged under farmer
70 conditions. Very little effort was spent on breeding varieties with resistance to mirids or other
71 insect pests. Field observations usually gave strong indications that mirids caused less
72 damage to some Trinitario selections (e.g. SC1) than the common West African Amelonado
73 (Anon. 1946). This was confirmed by Adu-Acheampong (2009), who identified SC6 as one
74 of the tolerant selections to fungal-induced dieback disease in cocoa. In compiling its list of
75 recommended varieties to the seed gardens, CRIG takes a firm line in rejecting varieties
76 susceptible to swollen shoot disease and encourage the development of resistance to black
77 pod disease. Unfortunately, the Institute does not follow an equally firm policy for insect
78 pests.

79 Insecticides (nicotine sulphate and DDT) were first introduced in the 1940s against mirids
80 because accumulated knowledge highlighted these insects as the most important pests. In the
81 following years, several insecticides including endrin, dieldrin, heptachlor and lindane)
82 against mirids were introduced, which were also aimed at the control of mealybugs
83 (*Planococcoides njalensis* (Laing), *Planococcus citri* (Risso) and *Ferrisia virgata* (Ckll))
84 which are vectors of cocoa swollen shoot virus disease. Unfortunately, insecticides were
85 applied prophylactically and at times when the pests were already present in damaging levels.

86 The percentage of cocoa trees that was treated with insecticides in the 1950s is difficult to
87 estimate accurately, but it rapidly increased in the 1960s (Johnson, 1971). Cocoa output
88 reached an all-time high of 560,000 tonnes in 1964/1965. Nearly all the insecticides used
89 were against mirids due to their relative high economic importance while the adoption of
90 insecticide use for other insect pests was slower. Later on, a growing concern for the
91 environment and for the conservation of wild life has been raised. At present, environmental
92 and consumer safety dictate the sustainable usage of chemicals. In this connection cocoa
93 farms are unique because of the large areas they occupy (nearly 2 million hectares in Ghana)

94 which is a major factor to be taken into account when considering the strategy for pest
95 control.

96

97 During the last two decades, and especially since 2000, there have been very significant
98 developments in nearly all aspects of cocoa pest insect control. Farmers have become very
99 conscious of the importance of insect pests, and data accumulated in mirid surveys on cocoa
100 have enabled objective assessments to be made (Adu-Acheampong *et al.*, 2014). Although
101 data on yield and financial losses due to pests are not readily available (due to varying farm
102 management systems), surveys demonstrated clearly that mirids and stink bugs are the most
103 important pests (Padi and Owusu, 2001).

104

105 The field of mealybug-vector control has seen fewer successes. The use of systemic
106 insecticides such as Azodrin (Monocrotophos SC –add the pedigree of the chemical that was
107 used, always use the active as trade names may vary in different countries) was a much more
108 convenient way of controlling swollen shoot virus vector in cocoa. The method suffered a
109 setback when it was detected that the chemicals (mainly organophosphate insecticides)
110 caused tainting of beans (Owusu-Manu, 1977).

111 For control of pod feeding insect pests, the present system of insecticide usage ensures that
112 pests are kept at a very low level. A possible danger now is that farmers faced with increased
113 insecticide costs have tended to procure cheaper unapproved insecticides and omit the
114 registered insecticide treatment. This calls for an urgent need to make the approved
115 insecticide products sufficiently available (in pesticide retail shops) so as to cause a reduction
116 in prices through market competition.

117

118 Improvements in the monitoring and forecasting of the major pests on the new varieties of
119 cocoa recently became evident (Ackonor and Abdul-Karimu, 2004), but the shift in
120 dominance between the two important mirid species is not adequately understood, and should
121 be studied further. Cultural practices which reduce serious insect pest attacks should
122 obviously play an important part in a control system. Such practices may include pruning,
123 chupon removal, agro-forestry, shade management, removal of alternative hosts, weeding and

fertilizer application (Cocoa Manual, 2012). Apart from these, the main emphasis in insect pest control will be on the use of resistant varieties reserving the use of chemicals for when economic threshold levels are exceeded.

Biological control

Past observations in Sierra Leone indicated low levels of mirid infestation. This prompted a search for natural enemies in Sierra Leone and the Congo but no significant effort to introduce natural enemies have thus far being done.

Host plant resistance

Nearly all the damage to cocoa trees of the 1950-1960s was associated with the growing of very susceptible varieties including Amelonado (Marchart and Collingwood, 1972). But no variety has expressed a satisfactory level of resistance to *S. singularis* and *D. theobroma*. In one of the few studies to address the issue, Adu-Acheampong *et al.* (2007) found that many local and international cocoa selections were highly preferred by mirids as suitable hosts for feeding and oviposition. This apparent lack of genetic variation in host preference requires further investigation, especially since genetic variation for resistance has been observed in several other systems (Byers *et al.* 1996, Strong *et al.* 1996). However, the development of a strategy for pest control could include varieties resistant to dieback disease resulting from hemipteran related fungal invasions as was shown by Adu-Acheampong, (2009). Identification and categorization of sources of resistance for developing pest resistant cocoa varieties should be pursued by biotechnology and traditional plant breeding. Observations at CRIG have shown that by mixing several varieties (each of them contributing a different form of genetic resistance), pest outbreaks can be reduced (Ackonor and Adomako, 2004). The push-pull effect through use of semio-chemicals to repel insect pests from the crop ('push') and to attract them into trap crops ('pull') must be exploited in future IPM strategy. Farmers seem to have understood the need for cocoa varieties as well as shade trees and food intercrops. It will be interesting to see whether this work will lead to at least a partial solution, of the cocoa mirid problem.

Monitoring and prediction

Hemipteran pest populations in cocoa are spatially and temporally patchy with many individuals exploiting cryptic habitats (Williams, 1953). An ability to predict or forecast severe outbreaks of pests is obviously an advantage when planning control programmes as that can lead to the selective, timely and precise use of chemicals.

Information from farms can be collected and fed into a central computer database, which can be managed by CRIG and the Cocoa Health and Extension Division of Ghana Cocoa Board. These organizations can receive information from many sources apart from their staff, notably the representatives of the many licensed cocoa buying companies and certification agencies serving farmers, as well as directly from farmers themselves. This information can be processed and released at fortnightly or monthly intervals for use on radio, television and the press. Farmers can receive useful guidance on the pests they should be looking out for. An improvement in the use of information dissemination services would lead to timely awareness of insect pest problems in cocoa farms as well as drastically reduced response times.

There is, however, very little information which can be used to predict the spread of pests. Whilst it is unlikely that spraying for insect pest control could be based entirely on prediction systems, a planned programme of timely sprays could be modified if the status of the biology of the specific insect pest was known. For example, that certain weather conditions might be favourable for the spread of a particular insect pest. Moreover, it is suggested that a monitoring programme where pest incidence as well as meteorological parameters are monitored should be established.

Chemical Control

Insecticide use in cocoa in the future should aim to supplement the control given by cultural practices, varietal selection and other methods, within an Integrated Pest Management programme. Experience gained from pest assessments at CRIG may lead to timely chemical treatments of cocoa which is sustainable in the case of cocoa pest control. It is common for farmers who have invested a lot of time and money in maintaining their cocoa farms to spray

prophylactically as a precaution against possible pest outbreaks (Adu-Acheampong *et al.*, 2014). It is also true that it is difficult to predict the development of some pests, such as stink bugs and stem borer adults in cocoa. Farmers may also be unable to spray a large area at short notice. Furthermore, a high yielding cocoa farm is more likely to be susceptible to insect pests than a low yielding cocoa farm (as there would be plenty of feeding and egg laying sites (Adu-Acheampong *et al.*, 2014), and with a higher potential profit the farmer can afford treatment costs. There should, thus, be separate timely recommendations for potentially high yielding cocoa farms as routine sprays on cocoa farms with lower than average potential yields are generally uneconomical.

Where insecticide use is planned, the approach should be flexible, taking into account the likely occurrence of pests but will also depend on factors such as geographical situation, varietal choices, and weather at critical times, as well as facilities available to the farmer to apply the chemical.

In recent years, insecticides registered for mirids have been used in more than 40% of cocoa farms in Ghana. Discussions with farmers suggest that the majority of the unsprayed cocoa farms would also have benefited from the government chemical treatment. There are currently no pest management action thresholds for hemipteran pests of cocoa but guidelines outlined in Table 1 provide a general recommendation). Visual assessment up to hand-height (Collingwood and Marchart, 1971) suggest that the rate of increase does not follow a definite pattern as severely devastated trees can have very low insect numbers. This is contrary to the case for many plant-pest relationships where severely damaged plants tend to have a lot more insect numbers some of which might undoubtedly be difficult to locate. There should, therefore, be a plan for timely treatment or contingency use of insecticide in cocoa farms for mirid and stink bug control. Some of the ways of considering insecticide use in cocoa are depicted in Table 1.

Table 1. Area-specific recommendation for mirid and stink bug control in cocoa

Prediction	Recommended treatment
1. Mirid and stink bug damage unlikely (<5 individuals/100	No spraying required; watch out
2. Mirid and stink bug slight/moderate (5-10 individuals/100 trees	Timed spray* spot treatment
3. Mirid moderate/severe (>10 individuals/100 trees)	Spray whole farm and repeat 4 weeks later.

*Timed spray – insecticide applied as soon as 3-5% trees or pods are affected. Source: Emmanuel Obeng, CRIG, unpublished data.

In planning a pest management programme, it is often necessary to consider the speed of chemical application which comes with a cost. Subsequently, it would be unreasonable to rely on a calendar spray system if large areas are involved. Probably it will be better to use more than one of the programmes suggested above in order to spread the work-load. Nevertheless, farmers are advised to move entirely away from calendar sprays and to optimize the biological control component by spraying strategically. This is difficult in most of Africa where not all farmers have the necessary spraying equipment. In a situation of a second pest, the insect would have to be considered separately or the pest would have to be treated irrespective of the mirid situation as has happened in the past with *Anomis* sp. and other caterpillars.

In June to August in many years, most pests tend to occur intermittently and the economic benefit from spraying is much less obvious than during occurrence of mirids (i.e. September to May). On most cocoa farms a sensible programme will be aimed at the control of mirids and pests such as termites. A two-spray regime programme- two sprays in the first quarter of the year to control mirids and stink bugs attacking cherelles (young cocoa pods) and a further two treatments in the major pest season – would cost (at 2014 prices) the equivalent of about GH¢80.00 (\$26.60) per ha for the insecticide. To this should be added the cost of labour and equipment for the treatment. Evidence from revenues from farmers' passbooks suggests that over the past few years most cocoa farms would or could? not repay this cost. However, as mentioned before, farmers who are achieving high yields find it necessary to have some insurance against insect pests and in these cases, the programme outlined would be justified.

The basic plan for insecticide use should, therefore, involve no, two or four strategically timed applications of recommended insecticides and the decision must be based first and foremost on the incidence of the primary pest with the present range of approved insecticides. Additional insecticides should only be used in exceptional cases when the key pest population increases beyond the economic threshold level. The blanket treatment of large areas with insecticides will undoubtedly have ecological consequences that may not be visible initially (unless effective bio-monitoring is carried out), but will manifest later and may be difficult to rectify. Furthermore, there is always the possibility that frequent spraying would encourage the development of insecticide resistant strains of the insect pests, destruction of beneficial non-target arthropods, and environmental pollution (e.g. contamination of water). Negative impacts on birds, reptiles and amphibians, which are of the

most efficient predators of insects, are also a very common side effects of the use of insecticides. Moreover, many of the chemicals used to control mirids and other insect pests listed by the WHO in class II Therefore it is particularly important that they are used only when necessary. Spot spraying (where localized areas are treated, and minimum amount of chemical is used) involves minimal cost and minimum contamination of the environment.

Government-assisted spraying ('mass spraying')

Government-assisted spraying of pesticides by recruited spraying teams in cocoa was started in 2001 (Adu-Acheampong *et al.*, 2004). This is a government intervention that aims to treat large areas quickly. Although the areas under treatment can be overwhelmingly large, many farmers need to plan their own treatment. Under the spraying programme dubbed 'mass spraying', delays in input supply to rural farming communities make timely application of pesticides difficult. Also, there are frequent cases where spraying teams may have been recruited from completely unfamiliar communities and which may hinder or delay spraying activities. Where chemicals are to be applied continuously in large blocks of cocoa farms and especially when these occur on mountain slopes, the provision of marked walking tracks would be an advantage, but the teams are often impatient. Nevertheless, the system appears to be beneficial as more than a 30% annual increase in yield was observed (When?). The application of sprays are likely to be much quicker if the farmers made provision for this type of spray application.

A recent survey (Adu-Acheampong *et al.*, 2014) showed that the spraying of cocoa is partially inefficient due to the large acreages involved, as well as the handling of large amounts of water. Expansion of the size of spraying teams across all communities and quicker filling from water tanks situated in large plantations is suggested as one method of speeding the process. Additionally, a more significant development will be the use of much smaller volumes of water through proper nozzle settings in applying the chemicals. The application technology is one field in which there have been remarkably little developments during the last 10 years. Recently it has been shown that for conventional insecticides, two application of 55 l/ha by motorised mistblower in February to May, and again in September to December at 28 days intervals per season, can give acceptable results on mirids and

possibly for stink bugs and other insect pests as well (Owusu-Manu, 2001; Adu-Acheampong *et al.*, 2014). However, more information is needed on the economics, as well as on the biological efficacy of the insecticides applied under the government spray programme.

Integration

When planning an Integrated Pest Management Programme, it is first necessary to consider the need for action regarding each insect pest separately and then to attempt to integrate the control measures into a system which may also include other chemicals such as herbicides, fungicides and fertilizers. Where possible, it is obviously convenient to apply more than one chemical at a time, but this can raise problems with timing and compatibility. The correct timing and frequency of chemical application is necessary for the chemical to be fully effective. It can be very risky in terms of accidental application of higher rates and also of phytotoxicity to compromise on the timing of a chemical application outside the limits set in the recommendation for its use. Most insecticides need to be applied in relation to a growth stage of the cocoa trees or the development stage of a pest; for many hemipteran pests, the phenology of the host plant is of critical importance. This can make planning easier and it should be possible to devise a system flexible enough to cope with most eventualities provided sufficient time is given to planning.

The use of insecticidal mixtures (cocktails) is becoming more common in cocoa in Ghana (Adu-Acheampong and Ackonor 2005). Current cocktail insecticides are mixtures from the two main insecticidal classes of neonicotinoid (e.g. imidacloprid SL 200g/litre, thiamethoxam SC 240g/litre, and acetamiprid EC 100g/litre) mixed with a synthetic pyrethroid (e.g. either bifenthrin EC 100g/litre or deltamethrin EC <10g/litre). Compatibility of chemicals often raises problems, since manufacturers can usually provide information on their own products, but it is difficult to do it for other products. The range of products and formulations, and the possible permutations for their use may make the task for compiling a compatibility table difficult.

Pheromones for cocoa insect pest control

Sex pheromones are widely used for a variety of species, but for mirids, they are not very effective (Sarfo, 2013). Aggregation pheromones are being used in some cases, though. Behavioural responses exploited to date in cocoa has been mainly the use of mating and sex attractants which detect adult male mirids only (Sarfo, 2013) and since the sex ration of the insect is near 1:1, population levels of the pest can be accurately inferred from trap catches. A great step forward would be made if male produced pheromones could be found and used to monitor female populations directly. Field observation suggests that a great deal of potential exist for use of synthetic pheromones for the cocoa stem borer, *Eulophonotus myrmeleon* Fldr. (Lepidoptera Cossidae) (Adu-Acheampong *et al.*, 2004).

Conclusion

The future strategy for insect pest management in cocoa should be based primarily on environmentally safe pest control alternatives. Intensified research and use of cultural practices and resistant varieties or pheromone-based mating disruption against Hemiptera supplemented with chemical treatments where necessary, will minimize the damaging effects of primary pests. Up to two timely applications of insecticides in February to May or September to December at 28 days intervals may be justified under certain conditions, but further applications should only be made when a serious pest problem arises. Because of the large areas under cocoa in Ghana (≈ 2 million ha), it is important to take into account the effects of chemicals, including their application, on the environment and on wild life.

Improvements of methods of surveillance and prediction would assist in early and more effective identification of specific pest problems. Development of efficient methods of application would enable a quicker and, therefore, more effective use of chemicals. Decisions on the use of chemicals by smallholder farmers must be based on consideration of factors including application methods, compatibility, correct timing and the resources available.

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