

# 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 the inadequate timing and inefficient application is probably reducing the viability of otherwise acceptable products. The future 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

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32

## 33 Introduction

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

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

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

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

58 Before the 1970s damage caused by mirids was well appreciated as well as the importance of  
59 dieback disease that follows mirid feeding on green unhardened tissue (pods and stem).  
60 Efforts were concentrated to understand population fluctuations of mirids on different  
61 varieties of cocoa, their distribution within trees as well as the effect of water stress on the  
62 incidence of pests. The tendency for average populations to remain low until August or  
63 September when a sharp rise began had an important bearing on the setting of another spray

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

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

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

104

105 The field of mealybug-vector control has seen fewer successes. The use of systemic  
106 insecticides such as Azodrin was a much more convenient way of controlling swollen shoot  
107 virus vector in cocoa. The method suffered a setback when it was detected that the chemicals  
108 (mainly organophosphate insecticides) caused tainting of beans (Owusu-Manu, 1977).

109 For control of pod feeding insect pests, the present system of insecticides ensures that pests  
110 are kept at a very low level. A possible danger in the future is that farmers faced with increase  
111 insecticide cost may procure cheaper unapproved insecticides and omit the registered  
112 insecticide treatment.

113

114 Pest control has seen improvement in the monitoring and forecasting of the major pests on  
115 the new varieties of cocoa, but the shift in dominance between the two important mirid  
116 species is not adequately understood, and hence there is more to learn about the insect  
117 complex of cocoa.

118

119 Cultural practices which reduce serious insect pest attacks should obviously play an  
120 important part in a control system. Such practices may include pruning, chupon removal,  
121 agro-forestry, shade management, removal of alternative hosts, weeding and fertilizer  
122 application. Apart from these the main emphasis in insect pest control will be on the use of  
123 resistant varieties reserving the use of chemicals for special purposes.

124

## 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. Except in so far as we have accumulated knowledge on the biology of the important mirids (*Sahlbergella singularis* Hagl. and *Distantiella theobroma* [Dist.]) and mealybugs, there has been no significant effort to introduce natural enemies.

## 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. But no varieties have 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, given that 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 traditional plant breeding. Recent 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. 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 intelligence 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 reduce response time.

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 it was known. For example, that certain weather conditions might be favourable for the spread of a particular insect pest.

## **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 assessment at CRIG may lead to timely chemical treatment of cocoa which is sustainable in the case of cocoa mirid control. It is common for farmers who have invested a lot of time and money in maintaining their cocoa farms to take to spray prophylactically as a precaution against unexpected developments of pests. It is also true that the development of some pests, such as stink bugs and stem borer adults in cocoa, is difficult to be predicted at present and a farmer also may 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, therefore, be separate timely recommendation for potentially high yielding cocoa farms. Routine sprays on cocoa farms with lower than average potential yield is generally uneconomical.

Where insecticide use is planned, the approach should be flexible, taken into account the likely occurrence of pests depending on such factors as geographical situations, varietal choice, 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 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. 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 might be as shown 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 (<20 individuals/100         | No spraying required; watch out            |
| 2. Mirid and stink bug slight/moderate (20-50 individuals/100 trees | Timed spray* spot treatment                |
| 3. Mirid moderate/severe (>50 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.

In planning a pest management programme, it will be necessary to consider the speed of chemical application. It would be unreasonable to rely on a calendar spray if a large area is involved, and it is probably better to use more than one of the programmes suggested above in order to spread the work-load. The possibility of the likely occurrence of a second (or more) insect pests will only arise in some circumstances, e.g., *Anomis* sp. caterpillars in the Volta, Eastern and Ashanti Regions or stem borer adults in highly susceptible varieties, and it may not always be feasible to include the appropriate insecticide with a mirid spray,

212 especially when this is a calendar spray. Nevertheless, farmers are advised to move entirely  
213 away from calendar sprays and use optimized biological control component by spraying very  
214 strategically. This is difficult in most of Africa where not all farmers have the necessary  
215 spraying equipment. In a situation of a second pest, the insect would have to be considered  
216 separately or the pest would have to be treated irrespective of the mirid situation as has  
217 happened in the past with *Anomis* sp. and other caterpillars.

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

229 The basic plan for insecticide use would, therefore, involve no, two or four timely  
230 applications of recommended insecticides against the primary pest. Additional insecticides  
231 should only be used in exceptional cases when a key pest population increases beyond the  
232 economic threshold level. Although there are no obvious environmental hazards associated  
233 with the use of the present range of approved insecticides, there may be objections to the  
234 frequent spraying of very large areas such as in the treatment of cocoa by the spraying gangs.  
235 Furthermore, there is always the possibility that frequent spraying would encourage the  
236 development of insecticide resistant strains of the insect pests, destruction of beneficial non-  
237 target organisms, and environmental pollution (e.g. contamination of water). Negative  
238 impacts on birds, reptiles and amphibians, which are of the most efficient predators of  
239 insects, are also a very common side effects of the use of insecticides. Moreover, many of  
240 the chemicals used to control mirids and other insect pests are in the WHO class II so that it  
241 is particularly important that they are used only when necessary. Spot spraying (where  
242 localized areas are treated, and minimum amount of chemical is used) involves minimal cost  
243 and minimum contamination of the environment.

244

245

246

247 **Government-assisted spraying ('mass spraying')**

248 Government-assisted spraying of pesticides by recruited spraying **teams** in cocoa was started  
249 in 2001. This is a government intervention that aims to treat large areas quickly. **Although** the  
250 areas under treatment can be **overwhelmingly large**, many farmers need to plan their own  
251 treatment. Under the spraying programme dubbed 'mass spraying', delays in input supply to  
252 rural farming communities make timely application of pesticides unfeasible. **Also**, there are  
253 frequent **cases** where spraying **teams** may have been recruited from completely unfamiliar  
254 communities **and which may hinder or delay spraying activities**. Where chemicals are to be  
255 applied continuously in large blocks of cocoa farms and especially when these occur on  
256 mountain slopes, the provision of marked walking tracks would be an advantage, but the  
257 **teams** are **often** impatient. Nevertheless, the system appears to be benefiting **>30%** annual  
258 increase in yield. **The application of sprays are likely to be much quicker if the farmers made**  
259 **provision for this type of spray application.**

260

261 A recent survey (Adu-Acheampong *et al.*, 2014) showed that **a part** of the spraying on cocoa  
262 is inefficient **due to** the large acreages involved, **as well as** the handling of large amounts of  
263 water. Expansion of the size of spraying **teams** across all communities and quicker filling  
264 from water tanks situated in large plantations is suggested as one method of speeding the  
265 process. Additionally, a more significant development will be the use of much smaller  
266 volumes of water through proper nozzle settings in applying the chemicals. The **application**  
267 **technology** is one field in which there have been remarkably little developments during the  
268 last 10 years. Recently it has been shown that for conventional insecticides, **two** application  
269 of 55 l/ha by motorised mistblower in February to May, and again in September to December  
270 at 28 days intervals **per season**, can give acceptable results on mirids and **possibly** for stink  
271 bugs and other insect pests **as well**. However, more information is needed on the economics,  
272 as well as on the biological efficacy of the insecticides applied under the government **spray**  
273 programme.

274

## 275     **Integration**

276     When planning an Integrated Pest Management Programme, it is first necessary to consider  
277     the need for action on each insect pest separately and then to attempt to integrate the control  
278     measures into a system which may also include other chemicals such as herbicides,  
279     fungicides and fertilizers. Where possible, it is obviously convenient to apply more than one  
280     chemical at a time, but this can raise problems in methods of application, such as timing and  
281     compatibility.

282

283     The correct timing and frequency of chemical application is necessary for the chemical to be  
284     fully effective. It can be very risky in terms of accidental application of higher rates and also  
285     of phytotoxicity to compromise on the timing of a chemical application outside the limits set in  
286     the recommendation for its use. Most insecticides need to be applied in relation to a growth  
287     stage of the cocoa trees or the development stage of a pest; for many hemipteran pests, the  
288     phenology of the host plant is of critical importance. This can make planning easier and it  
289     should be possible to devise a system flexible enough to cope with most eventualities  
290     provided sufficient time is given to planning.

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

300     In cocoa insect pest management systems, there is still little evidence of one control measure  
301     adversely affecting another. However, evidence suggests that cocoa extensively treated with  
302     lindane 3-4 decades ago not only have disrupted the ecological balance of hemipterans, it  
303     would have affected the entire arthropod complex (Owusu-Manu, 1976).

304

## 305 **Pheromones for cocoa insect pest control**

306 The appeal of sex attractants is that they are generally species specific and, therefore, they are  
307 often used for monitoring purposes. Pheromones are unfortunately not widely used for  
308 insects yet. Behavioural responses exploited to date in cocoa has been mainly the use of  
309 mating and sex attractants which detect adult male mirids only (Sarfo, 2013) and since the  
310 sex ration of the insect is near 1:1, population levels of the pest can be accurately inferred  
311 from trap catches. A great step forward would be made if male produced pheromones could  
312 be found and used to monitor female populations directly. Field observation suggests that a  
313 great deal of potential exist for use of synthetic pheromones for the cocoa stem borer,  
314 *Eulophonotus myrmeleon* Fldr. (Lepidoptera Cossidae) (Adu-Acheampong *et al.*, 2004).

315

## 316 **Conclusion**

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

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

331

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