

Future strategies towards mirid (Hemiptera: Miridae) and other insect pests control in cocoa (*Theobroma cacao* L.) in Ghana**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 application have increased the importance of insect pests on cocoa. Considerable progress was made at the turn of the last century replacing organochlorine insecticides for cocoa mirid control, but the inadequacy of appropriate timing and efficient application is probably reducing the efficiency of otherwise acceptable products. The future strategy for mirid and other insect pest control should be based primarily on the use of cultural practices of removal of excess chupons, shade management and host variety resistance aimed at minimising the effects of mirid associated dieback disease and stink bug deformation of pods. This control may then be supplemented in some cases by the use of insecticides in limited timely programmes up to two applications in February to May at 28-days intervals, depending on the pest population and damage levels and intensity of activity of pollinating insects, with further two applications in September to November when pest problem 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

30 **Running title:** Future strategy for mirid control

31

32 Future strategies for mirid (Hemiptera: Miridae) and other insect pests control in cocoa (*Theobroma*
33 *cacao* L.) in Ghana

34

35 **Introduction**

36 Mirids (*Distantiella theobroma* [Dist.] and *Sahlbergella singularis* Hagl.) are known for their
37 importance in causing losses in cocoa (*Theobroma cacao* L.) in West Africa. Crowdy (1947),
38 Owen (1956), Johnson, 1971 and Adu-Acheampong *et al.* (2012) outlined the problems
39 associated with mirid infestation. Stink bugs on the other hand are chronic pests of cocoa
40 (Owusu-Manu, 1976; Adu-Acheampong *et.*, 2014) whose nymphal and adult stages feed and
41 inject saliva into cocoa pods to liquefy plant tissues, causing premature ripening and
42 deformation of beans and pods. The feeding punctures of some stink bug species provide
43 entry points for fungal diseases (McGhee, 1997; McPherson and McPherson, 2000). Stink
44 bugs on cocoa have often been controlled indirectly by the application of insecticides applied
45 to control mirids.

46 In Ghana, it has become more difficult in recent years to achieve acceptable levels of control
47 of a number of the more important pests of cocoa than was the case three decades ago
48 (Owusu-Manu, 2001). There are several contributory reasons for this. Farmers have still to
49 learn about the best ways of using the new generation insecticides that have largely
50 displaced the organochlorine and carbamate compounds. The standards of insect pest control
51 in cocoa needed to guarantee high quality produce for global market outlets have increased,
52 setting targets for maximum residue limits of pesticides, which in some instances are clearly
53 not attainable.

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

58 Before discussing future strategy for mirid control in cocoa in Ghana it would be useful to
59 examine what has happened in the past.

Before the 1970s the damage caused by mirids was well appreciated and there was general awareness of the importance of dieback disease that preceded mirid feeding on green unhardened tissue (pods and stem). Efforts were concentrated to understand seasonal fluctuations on different types of cocoa, the distribution of mirids within trees and the effects of water stress were examined. Plant breeders at the Cocoa Research Institute of Ghana (CRIG) are developing varieties of cocoa that is resistant to swollen shoot and black pod and are high yielding, though this resistance does not seem to be durable enough when the varieties are challenged under farmer conditions. Very little attempt was made to breed varieties with resistance to mirids and other insect pests although field observations usually show that certain trees growing in the midst of an area blasted by mirids escape major damage suggesting that such trees are genetically resistant. Earlier reports gave strong indications that mirids caused less damage to the Trinitario selection SC1 than the common West African Amelonado ((Rep. Cocoa Res. Inst., Ghana, 1944/45 pp. 27-28). This was confirmed by Adu-Acheampong (2009) when identified SC6 as one of the tolerant materials to fungal-induced dieback disease in cocoa. In compiling its list of recommended varieties to the seed gardens CRIG takes a firm line in rejecting varieties susceptible to swollen shoot disease and encourage the development of resistance to black pod disease, but there is not an equally firm policy for insect pests.

Insecticides (Nicotine sulphate and DDT) were first introduced in the 1940s. As accumulated knowledge had highlighted mirids as the most important pests, the cocoa insecticides were for the control of this pest. In the next few years, several other mirid insecticides (endrin, dieldrin, heptachlor and lindane as sprays) were introduced, as were insecticides aimed at the control of mealybug vectors of cocoa swollen shoot disease *Planococcoides njalensis* (Laing), *Planococcus citri* (Risso) and *Ferrisia virgata* (Ckll)). These were timely applied, but in other situations, they were applied in high risk situations when the pests are present in damaging levels in the cocoa field.

The percentage of cocoa trees that was treated with insecticides in the 1950s cannot be determined, but it is speculated this may have rapidly increased in the 1960s with cocoa output rising and reaching an all time high of 560,000 tonnes in the 1964/65 season. Nearly all the insecticide use was aimed at the control of mirids. Insecticides for other insect pests such as mealybugs were adopted more slowly. The emphasis was the control of mirids. There has been a growing concern for the environment and for the conservation of wild life. In this connection cocoa are unique because of the large areas they occupy – nearly 2 million

93 hectares in Ghana. This is a major factor to be taken into account when considering the future
 94 strategy for pest and insect pest control and especially  includes the use of chemicals. It
 95 seems unlikely; however, that the development in the next ten years will be as dramatic as
 96 those in the past decade, unless an insecticide for the control of mealybugs is developed.
 97 Future strategy  considered here is based on the application of currently available control
 98 measures and on lessons learnt in recent years.

99

100 During the last two decades, and especially since 2000, there have been very significant
 101 developments in nearly all aspects of cocoa insect pest control. Farmers have become very
 102 conscious of the importance of insect pests  and data accumulated in mirid surveys on cocoa
 103 have enabled objective assessments of the pests  current in current systems to be made
 104 (Adu-Acheampong *et al.*, 2014). Although data on yield and financial losses due to pests are
 105 not readily available (due to varying farm management systems), surveys demonstrated
 106 clearly that mirids and stink bugs are important, and in most seasons they are the most
 107 important pests. In occasional years there are significant and sporadic attacks by defoliators.

108

109 The field of mealybug-vector control has seen fewer successes. The use of systemic
 110 insecticides such as Az  n was a much more convenient way  controlling swollen shoot
 111 disease in cocoa. The method suffered a setback when it was detected that the chemicals
 112 (mainly organophosphate insecticides) caused tainting of beans (Owusu-Manu, 1977).

113 For control of pod feeding insect pests, the present system  stringent maximum residue
 114 limits of insecticides ensures that pests are kept at a very low level. A possible danger in the
 115 future is that farmers faced with increase insecticide cost may procure cheaper unapproved
 116 insecticides and omit the standard  insecticide treatment. However, it is unlikely that this will
 117 develop sufficiently to cause a significant problem. A high proportion of cocoa farms are
 118 grown in combination with food crops in the early years and we need a better understanding
 119 of the other factors in the environment which limits yield in cocoa, but there are unlikely to
 120 be any significant development in the control of mealybug vectors until effective biocontrol
 121 agents are developed. The control of pests, which tend to occur erratically such as defoliators
 122 (caterpillars), will continue to depend largely on successful methods for monitoring and
 123 prediction, though there is also the need for more environmentally friendly chemicals.

124

125 Pest control has seen improvement in the monitoring and forecasting of the major pests on
 126 the new varieties of cocoa that have been produced, but the shift in dominance between the
 127 two important mirid species (*Sahlbergella singularis* dominating in the last decade) is not
 128 adequately understood, and hence there is more to learn about the insect complex of cocoa.

129

130 The main problem of the past several decades has been with the control of termites and the
 131 strategy for termite control considered here is based largely on a plan to control these pests
 132 integrated as far as possible with measures for the control of pest.

133 Cultural practices which enable serious insect pest attacks to be avoided or reduced should
 134 obviously play an important part in a control system. Such practices may include pruning,
 135 chupon removal, agro-forestry, shade management, removal of alternative hosts, weeding and
 136 fertilizer application. Apart from these the main emphasis in insect pest control will be on the
 137 use of resistant varieties reserving the use of chemicals for special purposes.

138

139 Biological control

140 In the past, observation was made that the cocoa in Sierra Leone was little attacked by mirids,
 141 which prompted arrangements for search for natural enemies in Sierra Leone and the then
 142 Congo. Except in so far as we have accumulated knowledge on the biology of the important
 143 mirids (*Sahlbergella singularis* Hagl. and *Distantiella theobroma* [Dist.]) and mealybugs,
 144 there has been no significant effort to introduce natural enemies.

145

146 Host plant resistance

147 The development of a strategy for insect pest control will depend a good deal on the success
 148 of plant breeders in providing farmers with varieties with reasonably good and durable
 149 resistance to dieback disease resulting from fungal invasion of mirid feeding punctures and
 150 stink bug damage. Apart from cocoa mirid, against which no varieties have maintained a
 151 satisfactory level of resistance, nearly all the high damage intensity of the 1950-60s have

152 been associated with the growing of very susceptible varieties including Amelonado (Adu-
153 Acheampong, 2009).

154 Recent observations at CRIG have shown that by mixing several varieties, each of which
155 contributes different form of genetic resistance, the pest outbreaks can be reduced. Farmers
156 seem to have accepted the need to diversify in their choice of mixed cocoa varieties and
157 shade trees and food crop intercrops. It will be interesting to see whether this work will lead to
158 a practical solution, or at least a partial solution, of the cocoa mirid problem.

159

160 **Monitoring and prediction**

161 An ability to predict or forecast severe outbreaks of pests is obviously a big advantage when
162 planning control programmes. It can lead to the selective use of chemicals which is
163 biologically and economically the most efficient way of using them. Prediction systems on a
164 field or district level must be devised for cocoa mirids, stink bugs, stem borers, leaf and
165 pod feeding caterpillars.

166

167 For the next decade or so, monitoring and pest surveillance needs to be done on the farm and
168 at the district level. Monitoring a farm should not present the cocoa farmer with any great
169 difficulty. Whilst a monthly survey of cocoa farms in general should be made, it is
170 particularly relevant to concentrate more detailed observations on varieties and situations
171 where particular pests are most likely to occur.

172 Information from farms can be collected for particular farming districts and fed into a
173 centralised intelligence system which can be managed by CRIG and the Cocoa Health and
174 Extension Division of Ghana Cocoa Board. These bodies can receive information from many
175 sources apart from its own staff, notably the representatives of the many licensed cocoa
176 buying companies and certification agencies serving farmers, as well as directly from farmers
177 themselves. This information can be collated and released at fortnightly or monthly intervals
178 for use on radio, television and the press. This and other information should be also available
179 more locally on radio and on telephone information services. Farmers who can be persuaded
180 to use these services regularly can receive useful guidance on the pests they should be
181 looking out for. An improvement in the use of intelligence services would lead to earlier

182 awareness of insect pest problems in cocoa farms and quicker and more effective action in
183 dealing with them.

184 There is, however, very little information which can be used to predict the spread of pests.
185 Whilst it is unlikely that spraying for insect pest control could be based entirely on prediction
186 systems, a planned programme of timely sprays could be modified if it was known. For
187 example, that certain weather conditions might be favourable for the spread of a particular
188 insect pest.

189

190 Chemical Control

191 Insecticide use in cocoa in the future should aim to supplement the control given by cultural
192 practices, varietal selection and other methods. It is possible, of course, to select varieties
193 which have desirable agronomic or yield characteristics, but are very susceptible to insect
194 pests, and these must be controlled by timely use of environmentally safe insecticides.

195 Experience gained from pest assessment in CRIG is to timely treatments of cocoa which
196 is worthwhile in the case of cocoa mirid control. It is common for farmers who have invested
197 a lot of time and money in maintaining their cocoa farms to take to part unnecessary
198 spraying as a precaution against unexpected developments of pests. It is also true that the
199 development of some pests, example, stink bugs and stem borer adults in cocoa is difficult to
200 predict at present and a farmer may be unable to spray a large area at short notice.
201 Furthermore, a high yielding cocoa farm is more likely to be susceptible to insect pests than a
202 low yielding cocoa farm (as there would be plenty of feeding and egg laying sites [Adu-
203 Acheampong *et al.*, 2014]), and with a higher potential profit the farmer can stand the cost of
204 timely treatments better. There should, therefore, be separate timely recommendation for
205 potentially high yielding cocoa farms. Cases for routine sprays on cocoa farms with lower
206 than average potential yield is generally uneconomical.

207 Where insecticide use is planned, the approach should be flexible, taken into account the
208 likely occurrence of pests depending on such factors as geographical situations, varietal
209 choice, and weather at critical times, as well as facilities available to the famer to apply the
210 chemical.

211 In recent years, cocoa mirid insecticides has been used in more than 40 per cent of cocoa
212 farms in Ghana, however, discussions with farmers suggest that the majority of the unsprayed
213 cocoa farms would also have benefited from the government chemical treatment. There
214 should, therefore, be a plan for timely treatment or contingency use of insecticide in cocoa
215 farms for mirid and stink bug control. Some of the ways of considering insecticide use in
216 cocoa are shown below.

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

Prediction	Recommended treatment
1. Mirid and stink bug damage unlikely	No spraying required
2. Mirid and stink bug slight/moderate	Timed spray* of all pockets
3. Mirid moderate/severe	Spray whole farm and repeat 4 weeks later.

218 *Timed spray – insecticide applied as soon as 3-5% trees or pods are affected.

219

220 In planning a programme, it will be necessary to consider the feasibility of applying to a large
221 area in a limited period. It would be unreasonable to rely on a calendar spray if a large area is
222 involved, and it is probably better to use more than one of the programmes suggested above
223 in order to spread the work-load. The possibility of the likely occurrence of a second (or
224 more) insect pests will only arise in some circumstances, example, *Anomis* sp. caterpillars in
225 the Volta, Eastern and Ashanti Regions or stem borer adults in highly susceptible varieties,
226 and it may not always be feasible to include the appropriate insecticide with a mirid spray,
227 especially when this is a calendar spray. In such circumstances, the second insect pest would
228 have to be considered separately or programme (5) above would be adopted irrespective of
229 the mirid situation as has happened in the past with *Anomis* sp. and other caterpillars.

230 In June to August in many years, most pests tend to occur unpredictably and the economic
231 benefit from spraying is much less obvious in cocoa where mirid occurs so consistently
232 (i.e. September to May). In most cocoa farms a timely programme will be aimed at the
233 control of mirids and pests such as termites. A two-spray regime programme- two sprays in
234 the first quarter of the year to control mirids and stink bugs attacking cherelles (young cocoa
235 pods) and a further two treatments in the major pest season – would cost (at 2014 prices) the
236 equivalent of about GH¢80.00 (\$26.60) per ha for the insecticide. To this should be added the
237 cost of application and yield loss through blowing away of potential flowers. Evidence from
238 revenues from farmers' passbooks suggests that over the past few years most cocoa farms
239 would not repay this cost. However, as mentioned before, farmers who are achieving high

240 yields find it necessary to have some insurance against insect pest and in these cases, the
241 programme outlined would be justified.

242 The basic plan for insecticide use would, therefore, involve no, two or four timely
243 applications of recommended insecticide. Additional insecticides should only be used when
244 a particular pest threatens to develop to significant levels. Such an approach should keep
245 costs under control and prevent significant losses in yield. It will also restrict the use of
246 insecticides to situations where they are likely to be most beneficial. Although there are no
247 obvious environmental hazards associated with the use of the present range of approved
248 insecticide, there may be objections to the frequent spraying of very large areas such as are
249 involved in the treatment of cocoa by the spraying gangs. Furthermore, there is always the
250 possibility that frequent spraying would encourage the development of insecticide resistant
251 strains of the insect pests, destruction of beneficial non-target organisms, and environmental
252 pollution (e.g. contamination of water bodies). Moreover, many of the chemicals used to
253 control mirids and other insect pests are in the WHO class II so that it is particularly
254 important that they are used only when necessary. Pocket spraying (where localized areas are
255 treated, and minimum amount of chemical is used) involves minimal cost and minimum
256 contamination of the environment.

257

258 Government-assisted spraying ('mass spraying')

259 Government-assisted spraying of pesticides by recruited spraying gangs in cocoa was started
260 in 2001. This is a government intervention that aims to treat large areas quickly. But the areas
261 under treatment can be overwhelming and many farmers need to plan their own treatment.
262 Under the spraying programme dubbed 'mass spraying', delays in input supply to rural
263 farming communities make timely application of pesticides is unfeasible, and there are
264 frequent inconveniences where spraying gangs may have been recruited from completely
265 unfamiliar communities and where access to the cocoa farms in the communities is not easy.
266 Where chemicals are to be applied continuously in large blocks of cocoa farms and especially
267 when these occur on mountain slopes, the provision of marked walking tracks would be an
268 advantage, but the gangs are many a times impatient. Nevertheless, the system appears to be
269 benefiting from an equivalent of >30 per cent annual increase in yield. the application of
270 sprays is likely to be much quicker if the operation is so much easier for the spraying gangs in
271 lined-up and well-laid trees in the plantations.

A recent survey (Adu-Acheampong *et al.*, 2014) showed that much of the spraying on cocoa is inefficient and a major factor limiting the speed of operation is the large acreages involved and the handling of large amounts of water. Expansion of the size of spraying gangs across all communities and quicker filling from water tanks situated in large plantations is suggested as one method of speeding the process, but a more significant development will be the use of much smaller volumes of water through proper nozzle settings in applying the chemicals. The supply of water 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, an application of 55 l/ha by motorised mistblower in February to May, and again in September to December at 28 days intervals can give acceptable results on mirids, it is possible this system is satisfactory for stink bugs and other insect pests alike. However, more information is needed on the economics of different methods of spray application on the biological efficiency of the insecticides applied in different cocoa farms under the government programme.

Integration

In planning the control of insect pests it is first necessary to consider the need for action on each insect pest separately and then to attempt to integrate the control measures into a system which may also include the application of 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 in methods of application, such as timing and compatibility.

The correct timing and frequency of chemical application is necessary if the chemical is to be fully effective. It can be very risky in terms of excess dosages and also of phytotoxicity to compromise on the timing of a chemical outside the limits set in the recommendation for its use. Most insecticides do not need to be applied in relation to a growth stage of the cocoa trees or the development stage of a pest. This can make planning easy 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, thiamethoxam, and acetamiprid) mixed with a synthetic pyrethroid (e.g. either bifenthrin, cypermethrin,

303 **deltamethrin**). Compatibility of chemicals often raises problems. Manufacturers can usually
304 provide information on their own products, but it is difficult to obtain information on the
305 compatibility of products of different manufacturers. The range of products and formulations,
306 and the possible permutation for their use may make the task for **complying** a compatibility
307 table impracticable.

308 In cocoa insect pest management systems, there is still little evidence of one control measure
309 adversely affecting another, though **it has been a long standing** evidence that cocoa
310 extensively treated with lindane 3-4 decades ago **destroyed natural balance of the sink bug**
311 **(Owusu-Manu, 1976), but the data are not conclusive enough to suggest the need for specific**
312 **action.**

313

314 **Pheromones for cocoa insect pest control**

315 The appeal of sex attractants is that they are generally **much more** specific, **and for**
316 **monitoring purposes** it it has not proven possible to use them in cocoa as the basis of very
317 **satisfactory control systems nor achieved improved effectiveness of insecticides at less cost**
318 **and contamination of the environment.** Behavioural responses exploited to date in cocoa has
319 been mainly the use of mating and sex attractants which detect adult male mirids only (Sarfo,
320 2013), **thereby providing an extra element of uncertainty into the interpretation of trap**
321 **catches in terms of infestation levels and cocoa farm damage.** A great step forward would be
322 possible if ways could be found of **using female pheromones to attract other females,** or if
323 male produced pheromones could be found and used to monitor female populations directly.
324 Field observation suggests that a great deal of potential exist for use of synthetic pheromones
325 for the cocoa stem borer, *Eulophonotus myrmeleon* Fldr. (Lepidoptera Cossidae) (Adu-
326 Acheampong *et al.*, 2004).

327

328 **Conclusion**

329 The future strategy for insect pest management in cocoa should be based primarily on non-
330 toxic pest control alternatives such as the use of cultural practices and resistant varieties or
331 pheromone-based mating disruption and supplemented by the use of chemicals where
332 necessary with the view to avoiding or minimising 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, and the development 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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