

Discussion

O. MOCHIDA: I understand DBM is serious in the Cameron Highlands, what methods do you recommend to farmers? and what methods do farmers use?

G. S. LIM: We recommend to spray only when necessary and preferably with the biological insecticide *Bacillus thuringiensis*. However, farmers more often than not prefer to stick to their old habits, such as spraying with 'cocktails' of insecticides at three to four day interval. We need to educate farmers first on pesticide usage.

A. SIVAPRAGASAM: Why didn't you use the Random Parasitoid equation of Royania/Roger to evaluate the parasitoids since it provides better evaluation of the parasitoids?

T. H. CHUA: I don't think the difference is substantial. In fact the Royania/Rogers equation involves more variables which could confuse the issue.

A. SIVAPRAGASAM: Did you consider the mobility of the host in your search rate evaluation between *Diadegma* (or *Apanteles*) and *Thyraella* since we know that the former is larval parasitoid and the latter a pupal one.

T. H. CHUA: No idea, though it is suggested that the stage of DBM larval parasitized could be a factor.

A. SIVAPRAGASAM: Why did you observe a large variation in the developmental time of *Diadegma* (12.5 to 19 days)?

T. H. CHUA: The slope of the line $\log a$ vs $\log P$ gives the values of m and they are: 0.63, 0.47 and 0.30 for *Apanteles*, *Thyraella* and *Diadegma* respectively.

E. D. MAGALLONA: Your formula for 'area of discovery' ends up with the unit area/number or the inverse of density. Considering that 'area' has an established usage worldwide, I think you could consider using different terminology for better understanding of your data amongs laymen and vice-versa.

T. H. CHUA: You may be right. However to avoid confusion, the standard terminology has been used.

M. P. FERINO: One reason you mentioned why *Diadegma* did not perform very well in the field as it did in the laboratory is the possibility that the parasitoid is susceptible to the effect of insecticides. Are you saying that the release area was treated with insecticide?

T. H. CHUA: With the possible exception of MARDI Research Station, all the other release areas (Table 1) were and are still frequently treated with insecticides. Even at MARDI Station, insecticide trials may sometimes be carried out.

Y. I CHU: Are there any host and habitat segregation or interspecific competition among those parasitoid wasps?

T. H. CHUA: No segregation of any sort has been observed. Interspecific competition is rather limited, even though the same stages of host may be acceptable to *Apanteles* (which actually prefers DBM larvae of instar II-IV) and *Diadegma*. Furthermore, Lloyd (1940) found that when *Apanteles* and *Diadegma* occurred together in a DBM host, neither showed any sort of superiority over the other.

I. MANTI: According to G. S. Lim, DBM parasitoids are dominant in Malaysia. Why the population of *Diadegma eucerothaga* is so low especially considering the fact that it is the most effective parasite? I wish you can introduce this parasite from Indonesia.

T. H. CHUA: We really do not know. However, indiscriminate and heavy use of insecticides cause high mortality of *Diadegma*, is a possible explanation.

O. MOCHIDA: Do you have any recommendation for DBM control in your country, if yes do the farmers follow it?

G. S. LIM: Yes, We have, but essentially on chemical usage only. Some farmers in Malaysia do follow it but most do not.

S. SUDARWOHADI: An integrated control program for DBM is being developed in Indonesia. The key component is biological control of DBM by parasitoid *Diadegma eucerothaga* Horstm. Application of insecticide should be done only when the population of DBM reaching the action threshold of 0.3 caterpillar/plant. We recommend the use of selective insecticide, *Bacillus thuringiensis*, to suppress the population of DBM. Farmers not always follow our recommendation and they regularly spray their cabbage fields once every week. As indicated everywhere, we need time to change the farmers' attitude.

E. D. MAGALLONA: It depends on the population in the particular area. In areas where pesticides use is quite heavy, there will be problems in overnight shift to other control agents. However, in low infestation areas or areas which are newly opened for crucifers, the use of cultural practices like crop rotation, barrier plants and physical barriers may be feasible. Definitely, the use of parasitoids and predators have not been adopted at a practical level. At the present time, in the absence of a concerted extension effort, the farmer relies solely on insecticides.

L. C. CHANG: Is there any difference in parasitism in open field and isolated area such as greenhouse. Do you think they will work better in isolated area?

G. S. LIM: In general parasitism will be higher in artificially-isolated conditions such as greenhouses or cages, because hyperparasitism is excluded. But there is no evidence that better control will be achieved in isolated areas than in the open field.

S. SUDARWOHADI: Rate of parasitism in open field depends on the host populations, while in isolated area such as greenhouse nearly 100% parasitism is possible. The parasitoid will work better in isolated area. However, the maintenance of an adequate supply of hosts is very important to maintain the parasitoid populations.

E. Y. CHENG: A larval parasite is the least desirable choice of parasite for the biological control of DBM. Why then is *Apanteles plutellae* still receiving so much attention?

G. S. LIM: It is not true that larval parasite is the least desirable choice of parasite for the biological control of DBM. In fact, larval parasites constitute the more effective agents and should be given priority. The successful deployment in Indonesia of *Diadegma eucerothaga*, a larval parasite of DBM, clearly demonstrates this. Similarly, the useful contribution of *Apanteles plutellae* (another larval parasite of DBM) as part of a parasite complex in Australia cannot be ignored.

E. D. MAGALLONA: Knowing the constraints in developing countries both from the stand point of institutional expertise and of operational capabilities, how do you propose to implement a successful biological control program against DBM?

G. S. LIM: This is a difficult question in that the successful implementation of a biological control program generally requires a good amount of initial resource, support

and understanding, from a fairly wide range of people (besides the scientist himself) who might be involved with the pest. Assuming the availability of only just the basic support but given a highly motivated staff I would advise that the first step is to import the key parasitoids if these are not already present. This may be done cheaply through the help of fellow scientists from another country where there is a stock culture or where the parasitoid(s) may be collected from the field. Following introduction, release and establishment, the impact may then be evaluated. If the pest is managed satisfactorily then studies need to be carried out to find means of maintaining the effective suppression. On the other hand if the control is inadequate investigations must then be pursued on how to exploit them effectively within the integrated control strategy.

P. J. SALINAS: What about birds and other vertebrates? In England birds are important predators of DBM. In Venezuela birds are probably more important than other predators. Do you have any observations to this effect?

G. S. LIM: I am aware of your studies in England regarding the importance of birds in relation to DBM management. In Malaysia we have also observed birds feeding on DBM larvae. However their real contributions have not been quantitatively evaluated.

N. WILDING: Your argument for the relationship between the abundance of parasitoids and DBM importance is very convincing but seems to have been considered in isolation; you did not mention predators, diseases, and abiotic factors. In the tropics, DBM seems to multiply faster and thereby outstrip its natural enemies.

G. S. LIM: I do agree with you that my treatment of this presentation deals only with the impact of parasitoids on the DBM in isolation from other biotic and abiotic factors which can be important as well. I am fully aware of this and the main reason, as explained in the introduction to my talk, is because studies and information on these other agents have been scanty and incomplete. Nevertheless, even with the parasitoid component alone biological control contributions can be enormous, and one of my objectives is to illustrate this here.

Although DBM multiplies faster in the tropics and may appear to be able to outstrip its natural enemies this may be so only if the latter are weak or are inefficient species. Devoting a lot of effort to such inherently inefficient species is evidently wasteful of time and resource. That was why I emphasized the need to be selective in the choice of the parasitoid species involved.

Appropriate exploitation of a crucially important species cannot be overemphasized, as may be illustrated by the introduction of *Diadegma eucerophagus* into Indonesia, where it provided successful control of DBM. This same example also negates the view that in the tropics natural enemies will be outstripped by the host's faster multiplication.

Y. I CHU: Have you observed any host feeding behavior of the parasitoid wasps?

G. S. LIM: No, we have so far not observed any host feeding behavior of the few parasitoids that we have personally studied, namely *Apanteles plutellae*, *Tetrastichus sokolowskii* and *Diadegma eucerophaga*. *Thyraella collaris* female enters the host cocoon and feeds at the site of pupation.

E. Y. CHENG: Alternative hosts are important for providing high parasitoid populations when the host population is low. How does this factor influence the DBM parasitoids?

G. S. LIM: Only a few alternate hosts of DBM parasitoids have so far been recorded, particularly for *Apanteles plutellae*. Even among these few, some are noted to be unnatural hosts while few have actually been confirmed as true hosts through proper

breeding studies. In general, it seems obvious that *A. plutellae* is oligophagous. In Malaysia, its range of alternative host species is restricted only to *Agrostis ypsilon* and *Crociodolomia binotalis*, both of which are also observed to be poorly exploited by the parasitoid.

Under more equable climatic conditions and the ever-presence of DBM in an environment of continuous and overlapping cropping as in many parts of the tropics, the alternative hosts, even if present, will usually not be of any importance as they are by contrast in the case of *Swammerdamia lutaria* on hawthorn, where the alternative host (*S. lutaria*) serves to bridge an overwintering larval generation of *Diadegma fenestralis* which is an important parasitoid of DBM in the United Kingdom.

E. D. Magallona: I do not quite agree with you that our salvation from DBM lies with biological control alone. Other control methods are still being used, and so is biological control. We are all aware of the adoption problem with biological control.

G. S. LIM: I did not say that biological control alone is the only solution to the DBM problem. It certainly constitutes a fundamental component that has proved to be highly effective, either by itself or supplemented by other methods. It should be noted that except for chemical insecticides and biological control, all other potentially useful approaches have yet to be demonstrated as being practically effective in large scale farm situations. However, with chemicals, many undesirable side effects exist and these are already well known.

While the inclusion of key natural enemies of DBM may not guarantee complete biological control (though complete successes do exist and have been achieved), marked improvements in the overall pest situation can invariably be expected.

With respect to adoption problems, this is not confined to biological control alone. Evidently, everything has its price. For example, in the case of chemical control its adoption may seem simpler, more straightforward and easier: probably it is because so simply adopted that we are facing so many problems in using chemicals. In order to minimize the latter, adoption at once becomes much more difficult through trying to use the chemicals judiciously and safely. It is thus my belief that each approach will have its own problem of adoption, and that for one this problem is not in anyway measurably less than for another, especially if we are considering proper and satisfactory adoption.

I. HELLWIG: The chemical industry recognizes the importance of biological control. Are your data on biological control based on field studies or lab studies?

G. S. LIM: The data presented here are predominantly from field studies.

T. MIYATA: On seriously damaged plants, the carrying capacity would be low and insect populations on them will be less than on treated plants. What were the initial populations of DBM in control plots?

G. S. LIM: In all the plots the initial population of DBM was negligible. Over time the build-up increased, largely in the control and Sevithion plots. That for the latter was however many times that of the control.

T. MIYATA: Sevithion seems to be selective against parasitoids. Elimination of parasitoids causes DBM resurgence. Did you find resurgence in parasitoid free-condition?

G. S. LIM: Sevithion is evidently selective against *Apanteles plutellae* but we do not know if other parasitoids will also be affected similarly. With regard to DBM resurgence in parasitoid-free condition, this has been observed to be common.

S. A. RAHMAN (COMMENT): Natural epizootics of GV of DBM occur in watercress fields in Hawaii, but not to a high degree. I presume GV of NPV will cause

epizootic in the tropics if conditions are right. Generally many factors such as high population, and type of food induce epizootics.

N. S. TALEKAR: Although GV works very well against DBM in laboratory, we find it is not effective in the field. We must apply frequently. Is there anything that can be done to improve persistence of GV in the field.

T. ASAYAMA: Granulosis is induced by dipping the DBM larvae in endrin solution for a few minutes in laboratory experiments. GV plus endrin may enhance the GV infection in the field. I think induction of latent virus is associated with the improvement of persistence.

R. I. ROSE (COMMENT): Early published work at AVRDC showed that activated carbon was the only adjuvant that appeared to provide UV protection, but it left the cabbage too dirty to be marketable.

T. ASAYAMA: We are conducting research on the control of the tobacco cutworm, *Spodoptera litura* by virus. In this project, we use amorphous silica, so called 'white carbon' as UV protectant at 0.1 - 0.2% of the spray solution.

R. F. HOU: Do you find any cross infection of DBM GV to other lepidopterous insects?

T. ASAYAMA: No, DBM GV is not infectious to any other lepidopterous insect pest of cabbage as evidenced by peroral inoculation studies.

R. F. HOU: Have you found NPV in DBM in Japan?

T. ASAYAMA: I have never seen the naturally occurring epizootics of NPV of DBM in my country. But P.V. Vail et al (J. Invertebr. Pathol. 20:216-217, 1972) show that NPV isolated from the alfalfa looper infects DBM as well as the cabbage looper in America.

I. MANTI: How effective is GV in the field for the control of DBM?

T. ASAYAMA: I have not yet tried the field application of DBM GV.

R. YEH: Do you have any data on comparative effectiveness of Bactospeine, Dipel, and Thuricide on the control of DBM?

E. BRUNNER: Yes, we do have limited comparative efficacy data for other competitive *Bt* products on the control of DBM. However, because experience has shown that it is extremely difficult to ensure statistically valid reliability when comparing biological insecticide efficacies, even for the same product in a given trial, we decided to publish no such comparisons in this paper dealing specifically with Thuricide HP.

R. YEH: Is there any difference between serotype I and serotype III in terms of DBM control?

E. BRUNNER: We have no data. Serotype I, for regulatory reasons, has been replaced by serotype III.

E. D. MAGALLONA: *Bacillus thuringiensis* appears to be a good control agent and yet it is not widely used. It may have acceptance problems. Could you comment on this?

E. BRUNNER: Factors affecting product acceptance are — selectivity (this can be regarded both as advantage and disadvantage), toxic action only by ingestion, time of application, feeding habit of larvae, the lower reliability of product against some genera such as *Heliothis* and *Spodoptera*, and relative high cost of *Bt* products.

C. N. SUN: Is there any possibility of isolating a much more potent strain of *Bt* against DBM?

E. BRUNNER: We are working in this direction.

R. I. ROSE: Different strains of *Bt* have now been found that show enhanced activity against *Heliothis* sp and *Spodoptera* sp and now possibly DBM. Genetic engineering is also making new varieties of *Bt* available. Tests are underway to identify and develop *Bt* strains more specific to important pests like DBM.

S. A. RAHMAN: Your data show high DBM mortality five to ten days after *Bt* application. We know *Bt* is inactivated by sunshine. Is the mortality due to residues of *Bt* or high inoculum level to start with?

E. BRUNNER: It is indeed true that the activity of *Bt* deposits decline with the passing of time, depending on formulation type, due to a number of factors such as sunlight radiation, as happens also with many chemical insecticides. However, once *Bt* deposit has been ingested by larvae of susceptible lepidopterous species, the larvae surely succumb, provided that they have ingested enough viable crystals to generate sufficient gastric tract infection. Feeding activity is important, as well as larval body weight, when considering mortality due to *Bt*. Early larval stages are more susceptible to *Bt*, and hence the need for properly timed applications to coincide with the presence of early larval stages. After ingestion of *Bt*, the larvae stop feeding, causing no further damage to the crop, yet the death of these larvae occurs only two to five days later.

R. S. REJESUS: What is your prediction or speculation regarding DBM developing resistance to *Bt*?

E. BRUNNER: To date, there has been no case reported of development of resistance by any insect species to *Bt* under field conditions. Therefore, we consider it to be extremely unlikely in the case of DBM.