PN-AAE-336

REPRINT NUMBER

13

Biology/Chemistry Section
Technology Branch
Communicable Disease Center
P.O. Box 769, Savannah, Ga. 31402

Bull. Org. mond. Santé
Bull. Wld Hlth Org. } 1963, 29, Suppl., pp. 63-68

Research in Vector Control

K. D. QUARTERMAN

Current research on vector control is directed mainly at finding answers to the problem of resistance. Despite considerable advances in knowledge of the genetics, biochemistry, physiology, and ecology of resistant vectors, the only practical answer found so far has been the development of new, substitute insecticides. At present the operational needs of existing large-scale control or eradication programmes swallow up much of the funds, personnel and facilities that might otherwise be devoted to basic research. Moreover, to back up these programmes, there is a continuing need for applied research on such questions as the packaging of pesticides, improvements in equipment and the development of new formulations. The author gives examples of applied research already carried out or in progress and indicates some areas of both basic and applied research demanding urgent attention. Like other participants in the seminar, he stresses the fundamental importance of ecological studies. He also examines the concept of integrated vector control and points out that the realization of this concept presupposes close co-ordination between basic and applied research, laboratory and field studies, and investigations on chemical and non-chemical vector control measures.

There seems to be general agreement that the development of resistance to insecticides by many of the most important disease vectors has been responsible for a major portion of current research on vector control. Although the amount of research devoted to the various facets of resistance has not been enough to satisfy those workers who are most concerned with the problem, it has nevertheless been of considerable magnitude and duration.

During the 15 years since resistance to DDT and to the newer insecticides first appeared, significant advances have been made in our knowledge of the genetics, biochemistry, physiology, and ecology of resistant vectors. For the present, however, the simple truth is that no satisfactory answer to resistance has been forthcoming except to find new substitute insecticides as the vectors have developed resistance to the old ones in use. As long as this continues to be true, much research will have to be devoted to the search for new and improved insecticides. At the same time, it is obvious that even greater research efforts need to be devoted to other aspects of the resistance problem—detection, measurement, elucidation and solution.

[1] Chief, Technical Development Laboratories, Technology Branch, Communicable Disease Center, Department of Health, Education and Welfare, Savannah, Ga., USA.

At this seminar, there has been general agreement upon the need to plan for a change-over from malaria eradication to vector control in countries where malaria eradication is nearing completion. However, before effective and efficient national vector control programmes can be undertaken, research in vector control must provide some essential guidance. After all these years of intensive study on malaria there are still wide gaps in our knowledge of the ecology of both the disease and its vectors. To avoid the same predicament with other vector-borne diseases, research on their ecology should begin immediately.

The competition for funds, personnel and facilities from other scientific, industrial, health, and governmental activities will inevitably limit the research that can be devoted to vector control problems. As long as millions of people continue to die annually from vector-borne diseases, the operating needs of existing large-scale programmes for the control and eradication of vector-borne diseases must receive first claim on the funds, personnel, and facilities available for vector-control research. Long-term basic research may eventually provide more effective, more economical, and safer vector control methods. In the meantime, however, applied research must be carried on at a sufficient level to

provide the operational programme with the necessary tools not merely to maintain the present rate of progress in the control of vector-borne diseases but to accelerate that progress.

APPLIED RESEARCH

Examples of the type of applied research needed to back up operational programmes include packaging for pesticides, equipment development, and formulation development. Under a reimbursable contract with the US Agency for International Development, the Communicable Disease Center has been conducting studies on some of these questions for almost 10 years.

Packaging

Wettable powders of DDT and other insecticides, used in huge quantities in malaria eradication, have been packaged in cylindrical, fibre-board drums for overseas shipment. Shipping costs could be reduced by hundreds of thousands of dollars annually if these insecticides could be packed in rectangular containers which would eliminate the waste of shipping space involved in the use of the cylindrical containers. Preliminary studies indicate that strong, corrugated paper boxes may be suitable for shipping these insecticides. Field trials involving shipping, storage, and handling are now in progress to ascertain the feasibility of using such boxes.

Equipment

The malaria eradication effort was mounted on a global basis after a number of years of large-scale control programmes in many countries. Although the spraying equipment used in malaria eradication had reached an advanced stage of development by the time the global eradication effort was begun, further improvements have continued up to the present time, and each of these has resulted in more effective and/or more economical spraying operations. Prior to the use of DDT in house spraying, hand sprayers were of flimsy construction designed for intermittent use in garden spraying or for other agricultural purposes. Since then the overall quality of hand sprayers has improved immensely, so that today a sprayer that will perform satisfactorily for many months of daily usage can be purchased at a reasonable price; specifications for sprayers have been developed by the Communicable Disease Center for the US Agency for International Development.

In addition to improving the hand sprayer as a whole, significant improvements have been made in specific parts that have resulted in marked savings in operational costs. For example, much effort has been devoted in past years to developing pressure and flow regulators to reduce the wastage of insecticide and to improve the uniformity of the spray applications. Expensive mechanical regulators proved inefficient in field use by unskilled spraymen. Recently the Communicable Disease Center, under its contract with the US Agency for International Development, has developed a simple, almost foolproof, efficient pressure and flow regulator that has no working parts to break down (Lonergan & Hall, 1959; Hall & Taylor, 1962). It consists of a flat rubber disc with an orifice in the centre that is placed in the nozzle assembly just preceding the nozzle tip. When the spray tank is pumped to a high pressure, the pressure on the rubber disc causes the orifice to close slightly, reducing the flow of material. As the tank pressure decreases with the discharge of the spray, the orifice slowly enlarges. With a single pumping-up of the sprayer, the entire tank contents can be discharged at a relatively uniform pressure and flow rate. Recent field tests on a country-wide basis indicate a reduction of approximately 15% in the quantity of insecticide used and an increase of approximately 10% in the number of houses sprayed daily,[1] owing to the fact that the sprayer has to be pumped up only once when the disc regulator is used. In addition, the discharge of the spray at a lower pressure reduces significantly the erosion of the nozzle tip and, hence, the frequency with which the tips must be replaced.

Insecticide formulations

The situation with regard to insecticidal formulations for use in malaria eradication has been comparable to that described for spraying equipment. Kerosene solutions or water emulsions were used in the earlier programmes. The first wettable powders were developed for use in agriculture where heavy power equipment was generally employed. It has required years of applied research and development to produce the presently available, high-quality wettable powders used in malaria eradication. The first wettable powder formulations contained only 25% of DDT or other toxicant, had poor qualities of suspensibility, and would not remain usable on prolonged storage. It has been less than a decade since

[1] Hall, L. B. & Galindo, C., unpublished report.

it was a common yearly experience for hundreds of tons of DDT wettable powder to be found unusable after storage in tropical areas from one spraying season to the next. This problem has been under study for about ten years by the Communicable Disease Center as part of its contract with the US Agency for International Development (Pearce, Gooden & Johnson, 1959; Pearce, Goette & Sedlak, 1959; Miles et al., 1959; Pearce, Miles & Goette, 1959; Miles et al., 1962; Miles, Goette & Pearce, 1962). Other governmental research laboratories in the USA and elsewhere, as well as many industrial research laboratories, have likewise devoted considerable effort to this problem. As a result of the combined efforts of all these agencies, specifications have been developed for wettable powders of DDT (and other chlorinated hydrocarbon toxicants) ensuring the procurement of high-quality products that will remain usable after storage in the tropics for more than a year.

While the problem of formulating satisfactory wettable powders for the chlorinated hydrocarbon insecticides appears to have been solved, it can be reasonably expected that much effort will be needed in this field to provide formulations of similar quality for insecticides in the organophosphorus and carbamate groups.

BASIC RESEARCH

Such mundane applied research and development lacks the lustre associated with highly complex basic research in genetics, biochemistry and physiology. Nevertheless, it is absolutely essential to the achievement and maintenance of an effective and efficient operational programme. While it can be expected that such applied research efforts will continue in the future, even at the expense of desirable basic research, efforts should be redoubled to achieve recognition of the immense need for a concurrent increase in research on those basic problems most likely to yield results useful to the operational programmes.

Ecology

To provide the necessary guidelines for a more intelligent approach to both applied and basic vector control research, more attention needs to be given to the ecology of the vector-borne diseases. A considerable effort is being devoted to studies on the ecology of the arthropod-borne encephalitides in the USA. Long-term investigations are in progress in California, Washington, Montana, Colorado, Texas, Florida, and Massachusetts, with less intensive and temporary efforts in other areas. Each year valuable new information is collected on the vectors and reservoirs of these diseases in different areas, on their relationship to the transmission of the encephalitides to man, and on the likelihood of achieving success with various control methods. Despite the progress made after a decade of studies, more information on the ecology of encephalitis is needed before a truly efficient control programme can be undertaken. The situation is much worse in many areas of the world where little knowledge exists on the ecology of a number of vector-borne diseases, the control of which is essential for proper socio-economic development. One shudders to think of the waste and inefficiency that would accompany the immediate introduction of the needed large-scale control programmes in such areas. It is none too soon to begin comprehensive investigations on the ecology of the important vector-borne diseases that affect large areas of the world, in anticipation of the control programmes that will inevitably be undertaken in the future.

Biochemistry and physiology

Substantially increased efforts should be devoted to basic research on the genetics, biochemistry, and physiology of the various vector species. In Dr. Craig's paper,[1] the interesting potentialities are discussed of the mass-rearing and introduction into natural populations of a strain of *Aedes aegypti* having an abnormally high ratio of male to female offspring. He also cites other possible manipulations of genetic factors to limit vector populations or to affect their ability to transmit disease. This approach has strong appeal in view of the widespread development of resistance to insecticides and mounting public concern over their increasing use.

Basic biochemical and physiological studies on the life processes of vectors also offer the hope of safer and more specific control measures than the use of pesticides. Sterilization by cobalt-60 or by chemical sterilants and its potential application in vector control are dealt with thoroughly by Dr Smith.[2] Another area in which very little work has been done, but in which research might reasonably be expected to offer rewarding results, is the study of the hormone systems of vector species. For

[1] See this Supplement, page 89.

[2] See this Supplement, page 99.

many years, undesirable plants were controlled by poisons such as arsenicals, with all the unwanted attendant dangers to man and animals. The degree of plant control achieved with poisonous chemicals often left much to be desired. The discovery that plants could be controlled through the use of hormones or closely related synthetic chemicals has led to the development of a variety of relatively cheap and highly effective chemicals that are much more effective and specific in their action against the various kinds of vegetation and are relatively non-toxic to other forms of life. It seems reasonable to expect that other hormonal substances could be found that would control disease vectors, that could be produced cheaply, that would be highly specific in their action against groups, if not individual species, of arthropod vectors, and that would be relatively non-toxic to other forms of life.

OTHER ASPECTS OF RESEARCH

Between the basic research just discussed and the clear-cut applied research mentioned earlier, there is an area involving elements of both basic and applied research in which there is also need for expanded effort. Recent investigations by the Communicable Disease Center have shown that more attention to the formulation of insecticides could improve the usefulness of existing compounds and broaden the range of chemicals that can be used effectively as insecticides. For example, for many years, highly volatile compounds were passed over with little attention as candidate insecticides for the treatment of houses for malaria control. Studies by the Communicable Disease Center during the past few years have demonstrated the feasibility of formulating a volatile insecticide (dichlorvos) so that it will be released as a vapour at a relatively uniform rate over long periods of time at concentrations lethal to vectors but safe for man (Mathis et al., 1959; Mathis & Maddock, 1961; Maddock & Sedlack, 1961; Mathis et al., 1961; Miles et al., 1962; Quarterman et al., 1963; Mathis et al., 1963; Funkes et al., 1963; Escudié & Sales, 1963; Schoof et al., 1963). In addition to being useful in the treatment of enclosed spaces such as houses, these formulations have other applications, such as in liquid poison bait dispensers for fly control (Kilpatrick et al., 1962) and in catch basins for mosquito control (Maddock et al., 1963; Brooks et al., 1963).

Techniques for evaluating the effectiveness of vector control measures are adequate for some types of insecticide, some types of application methods, and some vectors; they are woefully inadequate for others. For example, the hut test has been highly regarded as an effective means of evaluating residual insecticides for use in malaria eradication. However, recent studies by the Communicable Disease Center have shown that the hut tests as normally conducted, using window traps that remain in place overnight, are apt to be biased in favour of volatile insecticides owing to the fumigant action of the insecticidal vapours against the mosquitos caught in the window traps, as well as to the contamination of the traps by adsorption of the vapours. In tests at Savannah, Georgia, in 1962, in window traps attached to a hut treated with BHC at a dosage rate of 0.27 g/m^2, up to 70% mortality of test mosquitos was observed after only 1 hour's exposure in wire cages placed in the window traps, and up to 100% mortality after 2 hours. Similarly, with dieldrin applied at 0.6 g/m^2, up to 49% mortality of the test mosquitos was observed after 4 hours' exposure and up to 63% after 6 hours. In other studies with malathion at 2 g/m^2, complete kills of mosquitos were observed in entrance cages attached overnight to the outside of the treated huts, the mosquitos having failed to enter the huts through the narrow slit provided for that purpose (Mathis & Schoof, 1959). As all mosquitos that did not enter the hut died, it is not surprising that those that did enter and later escaped to the window traps likewise died. Unfortunately, most of the insecticides other than DDT that have been or are being evaluated as candidate residual insecticides are sufficiently volatile to introduce the bias just cited when evaluated by the conventional hut test procedure.

Another important aspect of the hut test is lack of knowledge of the activities of the mosquitos that escape from a treated house and the relationships between this ability to survive a single exposure and the overall effectiveness of the insecticidal treatment in reducing the vector population or in preventing malaria transmission. Over fifteen years ago, Ribbands (1947), in Assam, reported that in a test with a series of 5 huts, the second and fourth of which were untreated, almost as many dead mosquitos were found on the floors of the untreated huts as in the adjacent treated huts. The significant fact in this report is not that many of the mosquitos leaving the treated huts subsequently died, but that they entered another hut to rest. Had all the huts been treated, the mosquitos leaving one hut and

entering another would have suffered a second, additional exposure. This evidently occurs in normal malaria eradication programmes, in view of the demonstrated ability of some species (based on hut tests) to survive a single exposure and the almost total disappearance of the same species from large geographical areas following general house spraying for malaria eradication. Much additional research is needed to develop evaluation techniques that will reflect more adequately the true effectiveness of residual insecticides in malaria eradication.

INTEGRATED CONTROL

Convincing arguments have been advanced for the need for greater use of integrated control in vector control programmes. It is unfortunate, in my opinion, that the generally accepted definition of integrated control is the concurrent and judicious use of both chemical and biological control measures; in this context, " biological control " refers to such measures as the use of parasites, predators, and disease agents. It is my contention that in public health the definition of integrated control should include all measures directed toward accomplishing the objectives of controlling the disease concerned. For vector-borne diseases, this would include health education, drug therapy, and improved sanitation, as well as the complete armamentarium of vector control measures, not forgetting such approaches as drainage, screening, or the use of repellents, in addition to chemical and biological control.

Before integrated vector control can be practised effectively, there must be integrated vector control research. Close co-ordination should be achieved between basic and applied research, laboratory and field studies, and investigations on chemical and non-chemical vector control measures; consideration should be given both to the needs of local programmes and to providing guide-lines and support for country-wide control programmes for vector-borne diseases. Vector control measures must be co-ordinated with fish and wildlife management practices and must be mutually acceptable to agricultural and wildlife agencies as well as to the health authorities.

A multi-discipline team approach to vector control research by the individual laboratories and agencies will promote more effective local and national integration of research efforts. However, many vector-borne disease problems are international in scope. The World Health Organization has already done much to foster the international co-ordination of research on resistance to insecticides; it is now turning its attention to the international co-ordination of vector control research in general and, given full support, there is no reason why it should not accomplish this at an early date and then proceed to the international integration of control programmes for vector-borne diseases.

RÉSUMÉ

En dépit des recherches considérables effectuées depuis 15 ans, aucune solution autre que la mise au point de nouveaux insecticides n'a été en pratique apportée au problème de la résistance aux insecticides.

La nécessité de consacrer des fonds à d'autres activités scientifiques, industrielles, sanitaires ou gouvernementales limitera l'étendue des recherches consacrées aux problèmes de lutte contre les vecteurs. Mais, tant que des millions d'hommes meurent chaque année de maladies transmises par les vecteurs, les programmes opérationnels de lutte et d'éradication doivent recevoir une priorité absolue lors de la répartition des fonds et de l'affectation du personnel et des facilités que mérite la recherche pour la lutte contre les vecteurs. La recherche fondamentale à long terme peut fournir un jour à cette lutte des méthodes plus efficaces, plus économiques et plus sûres. En attendant, l'on doit maintenir la recherche appliquée à un niveau suffisant pour fournir aux programmes opérationnels les instruments nécessaires non seulement au rythme actuel de la lutte contre les maladies transmises par les vecteurs, mais encore à l'accélération de ce rythme.

Afin de dégager les grandes lignes d'une conception plus intelligente de la recherche (pure et appliquée) en matière de lutte contre les vecteurs, l'on doit porter plus d'attention à leur écologie. Des recherches plus poussées sur la génétique, la biochimie et la physiologie des différentes espèces de vecteurs faciliteront l'élaboration de nouvelles conceptions dans la lutte contre les vecteurs et une meilleure utilisation des méthodes existantes. Des recherches récentes sur les formules chimiques des insecticides ont montré l'intérêt qu'il y a à augmenter l'efficacité des insecticides existants et à élargir le registre des substances chimiques pouvant être utilisées comme insecticides.

Les techniques d'évaluation des méthodes de lutte contre les vecteurs sont appropriées à certains types d'insecticides, à certains types de méthodes d'application

et à certains vecteurs. Elles sont absolument inadéquates pour d'autres. C'est ainsi, par exemple, que des études récentes ont montré que les tests de case, utilisant des pièges de fenêtres, risquent de prévenir en faveur des insecticides volatils, du fait de l'action des vapeurs d'insecticides sur les moustiques pris dans les pièges de fenêtres comme de la contamination des pièges par les vapeurs d'insecticides. En outre, du fait que l'on ignore tout des activités des moustiques qui s'échappent d'une maison traitée, l'on ne peut fixer le rapport existant entre cette aptitude à échapper à un traitement unique et l'efficacité générale d'un traitement par insecticide pour réduire le nombre des vecteurs ou pour prévenir la transmission du paludisme. De nouvelles recherches sont nécessaires pour améliorer les techniques d'évaluation.

Ce qui importe avant tout, c'est la réalisation d'une lutte parfaitement articulée; cette articulation présuppose une coordination étroite entre la recherche pure et la recherche appliquée, les études de laboratoire et les études sur le terrain, les recherches sur les moyens chimiques et non chimiques de lutte contre les vecteurs.

REFERENCES

Brooks, G. D., Elmore, C. M., Jr., Schoof, H. F., & Carmichael, G. T. (1963) *Mosquito News*, in press

Escudié, E. & Sales, P. (1963) *Bull. Wld Hlth Org.*, **29**, 247

Funckes, A. J., Miller, S., & Hayes, W. J., Jr. (1963) *Bull. Wld Hlth Org.*, **29**, 243

Hall, L. B. & Taylor, J. E. (1962) *Bull. Wld Hlth Org.*, **27**, 279

Kilpatrick, J. W., Miles, J. W., & Schoof, H. F. (1962) *Pest Control*, **30**, 13

Lonergan, R. P. & Hall, L. B. (1959) *Bull. Wld Hlth Org.*, **20**, 961

Maddock, D. R. & Sedlak, V. A. (1961) *Bull. Wld Hlth Org.*, **24**, 644

Maddock, D. R., Elmore, C. M., Jr., & Schoof, H. F. (1963) *Mosquito News*, **23**, 69

Mathis, W. & Maddock, D. R. (1961) *Mosquito News*, **21**, 86

Mathis, W. & Schoof, H. F. (1959) *Amer. J. trop. Med. Hyg.*, **8**, 1

Mathis, W., Fay, R. W., Schoof, H. F., & Quarterman, K. D. (1959) *Publ. Hlth Rep. (Wash.)*, **74**, 379

Mathis, W., Miles, J. W., & Schoof, H. F. (1961) *Bull. Wld Hlth Org.*, **24**, 646

Mathis, W., St. Cloud, A., Eyraud, M., Miller, S. & Hamon, J. (1963) *Bull. Wld Hlth Org.*, **29**, 237

Miles, J. W., Allen, K., Woehst, J. E., & Grimm, L. (1962) *Bull. Wld Hlth Org.*, **27**, 275

Miles, J. W., Goette, M. B., Grimm, L. & Pearce, G. W. (1959) *Bull. Wld Hlth Org.*, **20**, 937

Miles, J. W., Goette, M. B. & Pearce, G. W. (1962) *Bull. Wld Hlth Org.*, **27**, 307

Miles, J. W., Pearce, G. W. & Woehst, J. E. (1962) *J. Agr. Food Chem.*, **10**, 240

Pearce, G. W., Goette, M. B. & Sedlak, V. A. (1959) *Bull. Wld Hlth Org.*, **20**, 921

Pearce, G. W., Gooden, E. L. & Johnson, D. R. (1959) *Bull. Wld Hlth Org.*, **20**, 913

Pearce, G. W., Miles, J. W. & Goette, M. B. (1959) *Bull. Wld Hlth Org.*, **20**, 947

Quarterman, K. D., Lotte, M. & Schoof, H. F. (1963) *Bull. Wld Hlth Org.*, **29**, 231

Ribbands, C. R. (1947) *Bull. ent. Res.*, **37**, 567

Schoof, H. F., Pearce, G. W., & Mathis, W. (1963) *Bull. Wld Hlth Org.*, **29**, 227