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Ecological Considerations in Scrub Typhus*

3. Methods of Area Control

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The best of the known methods for control of the chigger vectors of scrub typhus is the application of dieldrin to the ground and low-lying vegetation as a fog or spray at the rate of 2.5 lb to the acre (28 kg/hectare). This has produced a more than 91 % reduction in the numbers of Leptotrombidium (L.) akamushi *(Brumpt, 1910) and* L. (L.) deliense *(Walch, 1922) for at least 2 years. Aldrin applied at the rate of 2.25 lb per acre (2.5 kg/hectare) is also highly effective, but less so than dieldrin. Lindane at the rate of about 5 lb per acre (5.7 kg/hectare) ranks third, but offers protection for only about 2 months. Because of the potential hazards to wildlife when such long-acting compounds are used, application of organophosphorous or carbamate insecticides may be used instead in areas where reapplication every few weeks is feasible. Fenthion and arprocarb are promising compounds for this purpose.*

With the development of a variety of herbicides, it has become much more practicable to keep the environs of camp sites and buildings free of vegetation in scrub typhus endemic areas, thereby providing excellent control if insecticidal and anti-rodent measures are utilized as well. Control of the hosts of chiggers, which include many kinds of mammals and birds, is not feasible in sylvan foci, and the use of chemosterilants and systemic insecticides is regarded as impractical, at least in the foreseeable future.

Since insecticide can be properly applied only to limited areas, whereas in vast stretches of jungles, mountains and desert, as well as scrub terrain, scrub typhus may be endemic, a suitable program for its control must include methods of personal protection such as use of chigger-repellent substances and impregnated clothing.

Paradoxical as it may seem, scrub typhus is still an important disease today, even though it can be readily treated and we are aware of effective means of prevention. Thus, while scrub typhus responds dramatically to the use of broad-spectrum antibiotics in therapy, there still is a severe problem in diagnosis because scrub typhus may clinically resemble any of several other common diseases in endemic regions and the standard laboratory tests are so time-consuming that the diagnosis may become available only in retrospect. Compounds are known which, when applied to the ground, effectively control the chigger vectors for long periods, even 2 years or more, but the toxicity of these chemicals to man and wildlife has restricted their application on a large scale. Clothing-impregnants and repellents for use on the body have been shown to prevent attack by chiggers, but objections to the side-effects and certain characteristics of these compounds have limited their use. However, control of the chigger vectors by means of chemicals (insecticides or repellents) is still the most practical solution, since there is no satisfactory vaccine for scrub typhus, and chemoprophylaxis can be used only in exceptional circumstances (Smadel et al., 1949, 1950, 1951; Smadel & Elisberg, 1965). This paper deals with the question of area control; the use of repellents will be treated elsewhere.

It is necessary first to emphasize that we now know that scrub typhus infection may be present in terrain which formerly had been regarded as free

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of the disease, i.e., high in the mountains, in semi-desert or primary jungle (Traub & Wisseman, 1968a; Traub et al., 1967). Thus, scrub typhus (or tick typhus, or even malaria) may occur in the environs of the hill-station to which patients are sent to convalesce or where vacationers flock to enjoy leave. Such areas may also require control programmes, and deliberate avoidance of the fields of lallang, and building a camp-site in the primary jungle instead, may, therefore, be insufficient by itself as a precautionary measure.

In theory, there are several ways to attempt to clear an area of chigger vectors, all dependent upon the life-cycle and habits of the mites. Some of the measures, such as the use of residual insecticides, are aimed at killing the chiggers on the ground before they attach to a host (which in this case would, of course, be man). Some of these broad-spectrum compounds are also effective against the non-parasitic stages; since by killing insects in general, they deprive the nymphs and adult trombiculids of their food, i.e., insect eggs and soft-bodied insects. Another measure which works against the stages in the soil is to completely remove the vegetative cover in the target site by means of bulldozers, herbicides, etc. This radically alters the macro- and micro-habitats of the mites and of the mammals and birds that serve as their usual hosts. Burning the vegetation has the same effect. Measures directed against the rodents and other usual hosts of the chiggers indirectly affect the numbers of chiggers left to breed; one such method is to poison the sylvan hosts. Another potential weapon is the use of chemicals to sterilize the hosts and so reduce the populations, or else to employ systemic toxic compounds which would kill the ectoparasites feeding on those birds or mammals. These different methods are discussed in this paper.

RESIDUAL INSECTICIDES FOR THE CONTROL OF CHIGGERS

References and data dealing with the chlorinated hydrocarbons and certain other residual insecticides in the control of chiggers are cited in Traub & Dowling (1961), Tamiya (1962), Traub et al. (1954) and Bushland, (1958). Of all the compounds tested, dieldrin has proved to be the most efficacious. More than 2 years after dieldrin had been applied to the ground at the rate of 2.5 lb to the acre (= 2.8 kg/hectare) by means of a high-pressure sprayer or by a Swing-fog apparatus, there was an estimated reduction of over 91% in the chigger population of *Leptotrombidium* (*L.*) *akamushi* (Brumpt, 1910) and *L.* (*L.*) *deliense* (Walch, 1922) in each of the treated areas as compared with the controls (Traub & Dowling, 1961). Six months after treatment, the reductions were 98% and 97%, respectively, the same as that noted within 1.5 weeks after application. The data were based upon the numbers of chiggers noted in wild-caught rats trapped for the first time within the test-plots or released in their home territory in the plots after previous capture.

The Japanese investigators did not use dieldrin, but instead tested benzene hexachloride (BHC), lindane (the gamma isomer of BHC), diazinon, dinitrophenol ovotran-neotran mixture and chlorbenzilate (Tamiya, 1962) in the form of a dust, spray or mist, in tests using for criteria the numbers of chiggers noted on bait-animals or on plastic plates laid on the surface of the ground. Of these chemicals, they regarded BHC and lindane as " highly effective." For example, a dosage of 3–5 lb of active BHC per acre (3.5–5.7 kg/hectare) " totally suppressed " *L. scutellare* " for a period of more than eight weeks ", while a dosage of 4–6.5 pounds (4.5–7.5 kg/hectare) " yielded perfect control " against *L. akamushi* for 3–9 weeks. The other compounds were considered unsatisfactory.

Traub et al. (1954) reported that in tests necessarily limited to 6 weeks' exposure, aldrin, applied at the rate of 2.25 lb per acre (2.5 kg/hectare), was quite effective against *L. deliense* and *L. akamushi*, but less so than dieldrin sprayed at the same dose. Thus, after 5 weeks there were 75 times as many chiggers on rats trapped in the untreated plots as in the dieldrin-treated sector, and 25 times as many as in the aldrin-treated plots. These authors also cited reports indicating that chlordane and toxophene were very promising in this regard, but inferior to both aldrin and dieldrin.

Earlier studies had shown that DDT was of little value for controlling chiggers in New Guinea (Bushland, 1958) and the USA (Linduska et al., 1948) but had indicated the efficacy of BHC (McCulloch, 1947; Linduska et al., 1948) especially in the form of lindane. Audy (1949b), when summarizing methods of control, recommended lindane highly.

A variety of new classes of chemicals, such as the organophosphorous compounds and carbamates, have come into use against arthropods as a result of the effort to obtain satisfactory insecticides lacking the disadvantages which accompany excessively long-term toxicity, and which therefore would be less

likely to be toxic to man, domestic animals and wildlife. To be really useful against mites and ticks, any agent must have some residual effect, at least for some weeks, and, unfortunately, all such known compounds are, to some degree, toxic to vertebrates as well as to arthropods. The biochemistry and physiology at the cellular level of mammals, birds, insects and acarines is basically too similar to render it likely that a suitable residual-type insecticide will be found in the near future. One of the best known of the short-acting, but nevertheless effective, compounds is malathion, which produces a rapid reduction on the number of chiggers but which requires reapplication in about 2 weeks. Two of the more recently developed compounds in this group are highly promising against chiggers, namely, fenthion (Baytex), a phosphorothioate, and arprocarb (Baygon), a carbamate. According to unpublished data of the US Department of Agriculture, both of these compounds are somewhat superior to chlordane for about 2 months. Arprocarb seems to be more effective than fenthion. Chlordane does not rate as high as aldrin or dieldrin against known chigger vectors but nevertheless it is obvious that arprocarb and fenthion should be investigated further, especially against *Leptotrombidium*. If these compounds offer adequate control for 2 or 3 months, they would be eminently suitable where scrub typhus is seasonal, i.e., in Japan, where *L. akamushi* and *L. deliense* are active only in the summer. In the tropics, where the vectors breed continuously, such chemicals may not be suitable unless they simultaneously acted against a variety of insects in the soil, and thus served to deprive the nymphal and adult trombiculids of their food supply. Dieldrin is not only promptly lethal to the chiggers on the ground but has the added attribute of killing many kinds of arthropods, and both factors may contribute to the long-term effectiveness of that compound (Traub & Dowling, 1961).

On the basis of what we know now, the most effective chemical for the control of *Leptotrombidium* chiggers is dieldrin. If it is recalled that dosages as high as 60 lb of active DDT per acre (70 kg/hectare) have been used with little success against chiggers, and that, by contrast, dieldrin at 1/24th of this dosage provided excellent control for a minimum of 113 weeks, it would seem that a remarkably practical means of area control of vector chiggers is already at hand. Further, dieldrin can be dispersed as spray, mist or fog, and therefore application is easily accomplished, while the compound is sufficiently soluble so that the rain washes the toxicant from the vegetation and into the ground, where the mites live. For area control of vector chiggers, then, known or suspected foci such as resort areas, roadsides, camp sites, golf courses, mines, estates, borders of gardens and fields, etc., can readily be treated. In military operations, ranging from peace-time manœuvers to combat conditions, large areas of special interest can be sprayed from the air, and control of mosquitos and ticks, etc., can be effected at the same time. It is also worth emphasizing that there are data indicating that reduction in the chigger population following an application of dieldrin really would be expected to result in a decreased incidence of scrub typhus. Thus, in chemoprophylaxis tests in Malaya, 79% of the volunteers sitting in the grass in endemic foci at a time when the chigger index was greater than 375 per rat, contracted scrub typhus, but when the index was low—about 12 per rat—due to drought conditions, only 5% of the volunteers became ill (Traub & Frick, 1950).

There seem to be a number of reasons why the use of dieldrin for the control of chigger vectors has not become routine, even in the armed forces, despite the many points in its favour. One of the main factors seems to be lack of appreciation of the need for such a programme. The human cases of scrub typhus are generally scattered and the focus of infection not apparent or else is considered unimportant, except when large numbers of non-immune persons are exposed, which might occur, for example, when troops are taken into an area, pioneers are introduced into a newly cleared agricultural sector, or when labourers are working on a large hydro-electric scheme. As is often the case in the field of epidemiology, immediately after an outbreak of scrub typhus, a great effort is made to effect control, but in the inter-epidemic period, the precautions are often forgotten. This seems to be especially true for the armed forces of most nations. Perhaps the most important factor in the failure to use dieldrin in this way is its marked toxicity to vertebrates. The handlers as well as the residents, pets and wildlife in the treated area are all at risk in the event of improper application. However, dieldrin is not so much more of a residual or dangerous poison than BHC which, as Tamiya (1962) points out, is used regularly by farmers all over Japan. Dieldrin was effectively used by the Royal Air Force in Singapore for the control of scrub typhus (Lawley, 1957) and no untoward results were noted regarding toxicity. Its use for this purpose is recommended by the WHO Expert Committee on Insecticides (1963) and the United States

Army (US Army, 1962). Unless and until there is evidence that chiggers in endemic foci are resistant to this insecticide, it seems to us that dieldrin is the chemical of choice for area-control of the chigger vectors of scrub typhus, at least in those instances where the danger of disease in humans outweighs the possible detrimental effects upon wildlife, and this is almost axiomatic in the known endemic foci.

CLEARING GROUND-COVER

Removal of all ground-cover by felling and burning the trees, clearing and removing all the vegetation, then scraping the top soil with bulldozers, is an approved means of control of scrub typhus (Audy, 1949b; US Army, 1962). However, this is a highly expensive procedure and a great engineering effort is needed, even then it can only succeed under special circumstances, as when an area has to be cleared for construction of a camp, etc., or when a particularly notorious locus of disease is involved. Exposing the ground surface to the sun, especially in dry weather, rapidly renders the habitat unsuitable for all stages of the *Leptotrombidium*. The bulldozers also cover the old surface with several inches of hard-packed new soil, unearthing and then burying mites and rodents and their nests in the process. Rodents will not continue to live in an open area where there is no cover. In about 2 weeks in the tropics, areas so treated are essentially free of chiggers. However, it must be noted that once the rains start, then grasses, weeds, shrubs, rodents and mites reappear very rapidly, unless special precautions are taken. If insecticides, herbicides and defoliants are not applied and if anti-rodent measures are not taken, in a few months the area will have as many chiggers as before the operation, and in 6–12 months the locus may really be hyperendemic for scrub typhus. The history of the disease in the Second World War, in India and Burma, is replete with examples of precisely this occurrence (Mackie et al., 1946; Audy, 1949a; Traub, 1949).

In the past it was necessary to rely upon arsenicals and flame-throwers for the destruction of vegetation, but control of grass, shrubs and even trees is much simpler nowadays because of the availability of a variety of herbicides, defoliants and other chemicals affecting plant metabolism (US Department of Agriculture, 1965, 1967). Most of these compounds are effective against one class of vegetation, or are best applied in certain types of habitats, but it seems likely that suitable mixtures can be found for each of the sundry ecological habitats which are now known for scrub typhus.

For example, for virtually absolute " sterilization " of soil, as round camp sites, and buildings in endemic foci, chemicals like the benzoic acids, the uracils or the substituted-ureas could be used. The picolonic acids are particularly effective against woody plants, but at high dosages can kill all plant life. For use against brush and broad-leaved weeds, the phenoxyacetic acids, such as 2-4-5-T and 2-4-D, are recommended; these two chemicals are selective in the sense that they do not appreciably affect grasses. Bromacil (a uracil) or delapon (a chloracetic acid) may be used against grasses. The borates and chlorates, in heavy dosages, are frequently selected for use in arid climates.

It is obvious that great discretion and care must be employed whenever herbicides are used. Some of these chemicals are not only toxic to animals as well as to plants, but are persistent and so stable that they may eventually percolate unchanged through the soil into the water-table and eventually appear on farmland or in the water supply of towns and villages. Other substances may have a residual effect lasting far beyond the needs of the programme and may make it impossible to grow food or raise cattle in the treated areas for months, or perhaps years. The high cost of some of these chemicals (in the required dosages) is also a factor for consideration.

Some compounds can be used to kill only specific kinds of vegetation, and thus can be applied to cropland and grazing-grounds. If an inexpensive chemical were found that would be effective only against lallang (*Imperata cylindrica*), it would then be possible to control one of the most favoured habitats of the rats and chiggers associated with scrub typhus (Traub & Wisseman, 1968a). The local population would also benefit, since not only is this rapidly spreading, tough grass virtually useless but, as it is usually the climax-plant in ecological succession, it quickly covers vast stretches of land when forest is cut or when gardens are abandoned (as they usually are, after only one or two crops, in the practice of " shifting cultivation "). The result is a huge wasteland that may never revert to forest or be used again agriculturally.

The improper use of herbicides may do more harm than good in the control of scrub typhus. If, when the trees and shrubs are killed, the ground-surface is not kept bare of vegetation, nor treated with insecticide, ideal conditions for rats and chigger-vectors might soon develop. As discussed earlier

(Traub & Wisseman, 1968a), rats may thrive by feeding on the termites flourishing in the decaying roots of the dead trees and the area may soon become infested with *L. deliense*.

One of the most used methods of area control has been by cutting and burning the vegetation (Audy, 1949b; Tamiya, 1962; US Army, 1962) but, actually, by itself this is only effective for a few weeks (Traub & Dowling, 1961; Harrison, 1956). Thus, in Malaya it has been found that live rats can be readily trapped in heavily burned foci within 1 week of the fire, and that while the chigger population falls precipitously after the fire, it rapidly climbs to normal within 2 months (Traub & Dowling, 1961). Burning an area should therefore not be recommended for prevention of scrub typhus unless it is part of a programme which also includes: (1) clearing the land by bulldozer, and keeping it bare of vegetation; (2) rodent control; and (3) application of insecticide to the ground.

CONTROL OF CHIGGER HOSTS

Measures against rodents and other commensal small mammals in endemic areas should always be part of a scrub typhus programme on camp sites and other " suburban " areas. As mentioned in Part 2 of this series (Traub & Wisseman, 1968b), such mammals can harbour thousands of *Leptotrombidium* each, and " seed " the vicinity with engorged larvae that can develop into egg-laying adults within 9 weeks. The grass along the walks in such camps and the brush around the periphery can soon swarm with chiggers. Getting rid of the rodents and shrews deprives these chiggers of their most common hosts, and thus dooms most, if not all of them, provided that men do not replace the rats as hosts. This is a very important qualification, and it should be axiomatic that (1) a thorough insecticide programme should be launched against the chiggers on the ground *before* the rodent control campaign begins, and (2) all exposed individuals should use chigger-repellent substances on their persons and on their clothes. The various methods of rodent control are beyond the scope of this article. Measures against sylvan mammals are not considered to be practicable except for the precise sites in endemic foci which are inhabited by large numbers of people at risk. In such areas, however, it may be also advisable to attempt to control ground-birds such as quail, each of which also may carry thousands of *Leptotrombidium* (Traub & Wisseman, 1968b).

INDIRECT CONTROL OF CHIGGERS

Chemicals, such as the alkylating agents and radiomimetic compounds, that induce sterility but otherwise do not harm animals, are being tested for control of certain mammals and birds. In general they are the same as some of the chemosterilants currently being investigated for control of insects and discussed by Labrecque & Smith (1967). However, their use against the hosts of chigger vectors is obviously not feasible except perhaps against a few species of commensal rodents, and even these mammals would be host to chiggers for the rest of their sterile life. The hosts of such chiggers include virtually all birds and mammals in the habitats of the mites; and in our present state of ignorance regarding toxicity, effective dose and methods of application, it would manifestly be impossible to sterilize, but otherwise not injure, all the warm-blooded, small vertebrates of even a strictly limited locus. The size of the areas that would, in fact, have to be treated makes the task doubly impossible. Chemosterilants applied to bait that commensal rodents might carry back to nests away from the camp site may have potentialities. There is no possibility of using chemosterilants against the trombiculid nymphs and adults themselves in view of the diet (insect eggs, etc.) of the non-parasitic stages of chiggers and their habitat in the soil.

In theory, feeding systemic insecticides to the usual hosts of chiggers as a means of controlling the chiggers themselves appears to be an attractive idea. This approach, however, is also certain to be unrewarding in the foreseeable future, for a number of reasons. While a variety of compounds are known which can be fed to dogs or cattle and kill the ectoparasites of these mammals and yet not overtly adversely affect the host, the borderline between the effective dose for ectoparasites and the harmful dose for a mammal is extremely narrow. Even in domestic animals, which have been relatively well studied with regard to physiology and tolerance levels, undesirable side-effects have frequently been noted when systemic insecticides are given. Further, the drugs have to be taken over long periods. With a normal diet including earthworms, insects (of many kinds), amphibians, reptiles, small mammals, fruits, nuts, grass, leaves, etc., the wild mammals and birds in a scrub typhus locality could not systematically be dosed with systemic toxicants or chemosterilants. Even if a systemic or chemisterilant compound were known which could safely be applied in drinking-water, or by contact

with the ground or vegetation, the difficulties in application would be enormous—and dangerous to man.

SUMMARY AND CONCLUSIONS

In summary, it is stressed that in the light of our present knowledge, the best single method for area control of chigger vectors is by application of dieldrin, aldrin or lindane to the ground and low-lying vegetation. If this technique were employed in the environs of camp sites, mine buildings and other populated zones in endemic localities, and if exposed persons used any of the standard mite repellents, there would be no real scrub typhus problem (and few cases of arthropod-borne diseases!).

RÉSUMÉ

Bien que les antibiotiques à large spectre assurent un traitement efficace et rapide du typhus de brousse, l'importance de cette affection ne doit pas être sous-estimée. Le diagnostic clinique n'est pas sans présenter des difficultés et sa confirmation par les épreuves usuelles de laboratoire demande beaucoup de temps. On ne peut recourir qu'exceptionnellement à la chimioprophylaxie et, en l'absence de vaccin satisfaisant, la lutte contre l'infection doit être axée essentiellement sur la destruction des vecteurs au moyen des insecticides.

A cet égard, le traitement du sol et de la végétation basse par les aérosols ou les pulvérisations de dieldrine au taux de 2,8 kg par hectare donne les meilleurs résultats. On parvient à éliminer plus de 91% des populations larvaires de *Leptotrombidium* (*Leptotrombidium*) *akamushi* et de *L.* (*L.*) *deliense* pendant plus de deux ans. L'aldrine, à la concentration de 2,5 kg par hectare est également efficace. Quant au lindane, appliqué à raison de 5,7 kg par hectare, son action est très satisfaisante mais transitoire (deux mois environ). Cependant l'emploi de ces produits à rémanence élevée ne va pas sans inconvénients pour l'homme, les animaux domestiques et la faune, et l'on s'oriente plutôt vers l'utilisation des organophosphorés et des carbamates chaque fois qu'il est possible de répéter les traitements. Deux composés, le fenthion (Baytex) et l'aprocarb (Baygon) ont donné des résultats particulièrement prometteurs. S'il se confirme que leur action sur *Leptotrombidium* se maintient pendant 2 à 3 mois, ces produits pourront être utilisés avec profit dans certaines régions où le parasite n'a qu'une activité très saisonnière.

La lutte contre *Leptotrombidium* par l'élimination totale de la végétation a le désavantage d'un coût élevé et d'une efficacité très transitoire, de l'ordre de quelques mois. Elle doit être complétée par un traitement aux insecticides, aux herbicides et aux défoliants, dont la toxicité pour les animaux est souvent élevée. Les méthodes indirectes de lutte contre le parasite, comme la destruction des rongeurs et autres hôtes et l'utilisation des chimiostérilisants, sont également envisagées.

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