rarely fed); (*b*) the difficulty of finding infected specimens because of the very low endemicity of malaria in those places where *A. claviger* is predominant; (*c*) the existence of other more prominent vector species; and (*d*) the frequent movements of human populations—i.e., of parasite carriers—occurring in those areas, which complicate the picture.

Is *A. claviger* capable of sustaining alone the malaria endemicity in those villages where it happens to be a vector species—alone or in association with other species ? And, if so, what special control programme would be advisable in a general malaria eradication scheme ? An epidemiological investigation of the Lebanese *A. claviger* villages—such as Biré (Akkar), Markebta (Tripoli), Deir Billa (Koura), Medjel Baana (Aley)—where residual spraying but no larval control in the wells has been carried on for some years, to find if transmission has been eliminated, would provide an indirect answer to whether *A. claviger* control in wells is necessary in order to achieve rapid malaria eradication. But it would not show whether interruption of transmission had been achieved from the beginning.

One of the basic requirements for stopping control operations in an eradication scheme is that there is complete interruption of malaria transmission for at least three years. Residual spraying has been found not to control *A. claviger*, while larval control does. It would seem best, in the light of the probability that *A. claviger* maintains " casual transmission " of malaria for some time after the starting of residual spraying, to envisage larval control in wells simultaneously with residual spraying for at least the first two years. The eventual cost of such larval control would be much less than that of extending the residual spraying programme, and the chances would be decreased that other vector species might build up resistance—this in an area where *A. sacharovi* has already shown signs of decreased susceptibility to DDT.[o]

[o] Garrett-Jones, C. & Gramiccia, G. (1954) *Bull. Wld Hlth Org.*, **11**, 865

The Implications of *Anopheles sergenti* for Malaria Eradication Programmes East of the Mediterranean

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Experience gained in the control of malaria in the Jordan Valley during 1949 to 1952 showed that the main malaria vectors, *A. sergenti* and *A. superpictus*, especially the former, were successfully evading contact with DDT-sprayed surfaces by using caves and fissures in the hills as daytime resting-places, and were still capable of maintaining active malaria transmission in some villages.[a] In Israel, the importance of *A. sergenti* in maintaining malaria was demonstrated after the great reduction of the other

[a] Farid M. A. (1954 *Bull. Wld Hlth Org.*, **11**, 765

important malaria vectors, namely, *A. superpictus* and *A. sacharovi*.[b] As malaria eradication programmes in countries east of the Mediterranean are based mainly on the residual spraying of chlorinated hydrocarbon insecticides in the rural settlements, and as this method only affords partial control of the malaria transmitted by *A. sergenti*, as experienced both in Jordan and Israel, the problem of *A. sergenti* and its bearing on the eradication programmes needs especial consideration, which will be the subject of this article.

Distribution of *Anopheles sergenti* Theobald. The distribution of *A. sergenti* follows the Sahara belt, extending from the Canary Islands across North Africa, the arid areas in Asia Minor where the annual rainfall does not exceed 10 inches (250 mm), including Jordan, Israel, the Arabian peninsula, southern Syria and Lebanon, as well as a few spots in Iran, and west of the Indus. *A. sergenti* may be rightly called the "desert malaria vector", as it is capable of standing the very dry climate and the extremes of weather met in the desert during summer and winter.

In Egypt, *A. sergenti* has never been recorded in the Nile Valley proper, yet it is abundant in the western oases, in Fayoum Province, west of the Nile Valley, in the Sinai Peninsula, in the Suez Canal Zone, as well as along the eastern fringe of the Nile Delta.[c]

In Jordan it occurs in all the valleys that cut both plateaux east and west of the Jordan River and the Dead Sea, as well as in the Yarmuk-Jordan rift.

In Israel, *A. sergenti* is found throughout the country, but is most prevalent in the Jordan, Beisan and Huleh valleys, as well as in various localities in the Negev.[b]

Its distribution in Saudi Arabia is universal, but it is mainly found in the central plateau, and in the valleys of the Hedjaz mountains. In Yemen, it has been found in certain places, and has been recorded in a valley half way between Hodeida and San'a at an elevation of 3700 feet (1200 m) above sea level.[d]

A. sergenti occurs in southern Syria and Lebanon in the valleys leading to the Yarmuk River and Lake Tiberias, respectively. It exists in a spotty distribution along the coastal plain of Lebanon, but seems to have established itself in the northern Akkar plain. Berberian mentioned that its range extends as far north as Alexandretta and into Cecilia.[e]

One record of *A. sergenti* larvae has recently come from an isolated oasis west of Karbala in Iraq.[f] It exists in the Bahrein islands,[g] and has been recorded in the arid areas of southern Iran.

Bionomics of *A. sergenti*. *A. sergenti* breeds along stream beds, along edges of spring pools, in seepages along the foothills, and in rice fields.

[b] Saliternik, Z. (1955) *Bull. ent. Res.*, 46, 445

[c] Farid, M. A. (1940) *Riv. Malar.*, 1, 159

[d] Knight, K. L. (1953) *Proc. ent. Soc. Wash.*, 55, 212

[e] Berberian, D. A. (1946) *J. Palestine Arab med. Ass.*, 1, 120

[f] Pringle, J. & Garrett-Jones, G. (1956), personal communication

[g] Afridi, M. K. & Majid, S. A. (1952) *J. Malar. Inst. India*, 1, 427

It prefers shallow breeding-places not exceeding 15 cm in depth, where water is continuously renewed by a slow current or by continuous evaporation and more seepage, and where slight shade is offered by short vertical vegetation and sparse algal growths, or by the vertical banks of streams or rocks. It breeds alone in typical places, but sometimes it is associated with *A. superpictus*, *A. sacharovi*, or *A. pharoensis* (Egyptian oases), especially in rice fields. It prefers sweet water but can stand salinity up to 0.7%.[h]

In Jordan and Saudi Arabia, *A. sergenti* breeds all the year round, but its maximum breeding occurs in the autumn between September and November in its northern range, and later in the season and through the winter months in its southern range of distribution. No hibernation occurs in this species, which is capable of wintering as larvae or as adults. Bahr observed that adults of this species were active in Egypt in January 1917, even when the temperature was 1°C.[i]

Attempts by the writer in Egypt in 1939 to breed *A. sergenti* in captivity failed, even when the dimensions of the cage reached $3 \times 2 \times 2$ metres. Swarms of this species observed in Dakhla oasis during 1944 showed that they formed at dusk as well as before sunrise over mounds of earth 10 m to 20 m in height. Nuptial flights of this species seem to extend for some kilometres and many observers have noted that as many as 30% or more of the adult mosquitos caught in resting-places up to 6 km from breeding places consisted of males.

Saliternik reported that in Israel adults of *A. sergenti* often begin to appear in the settlements during the autumn in waves of varying density, at distances up to 6.5 km from the breeding-places, and that the wind appears to be a very important factor in the movements of this species and in the rate of dispersal from a given source.[h]

A. sergenti is an indiscriminate biter of both animals and human beings both indoors and outdoors. In Jordan the writer collected specimens of it during every hour of the night (7 p.m. to 5 a.m. in November 1952) from the bare legs of Bedouins sleeping in the open near their fields, the density increasing when air movement was at a minimum.

The indoor resting-places of *A. sergenti* are mostly to be found in the shaded and dark corners of a room or a stable, as well as in fissures, holes or in niches in the walls. In areas where there are natural caves and fissures in the neighbouring hills, a good collection of this species can be obtained from these caves and fissures. In some instances they were found in the dark spaces underneath rocks, or in holes in these rocks. In Yemen two female specimens were trapped on oiled paper at the entrance to rodent burrows in Wadi el Malah.[j] They seldom enter the bell-type tents used as a trap for *A. pharoensis*,[k] and although they bite Bedouins sleeping in their crude hair tents, they seldom remain inside after biting. They avoid light and are capable of changing their resting-places during the daytime in search of darker corners, such as the folds of dark clothing, empty pottery jars,

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[h] Saliternik, Z. (1955) *Bull. ent. Res.*, **46**, 445

[i] Bahr, P. H. (1949) *J. roy. Army. med. Cps*, **30**, 600

[j] Knight, K. L. (1953) *Proc. ent. Soc. Wash.*, **55**, 212

[k] Farid, M. A. (1940) *Riv. Malar.*, **1**, 159

pigeon-holes, or fissures and holes in the walls. They are very rarely found in dense foliage and seem to avoid places with high humidity. *A. sergenti* is a highly excitable mosquito and any change in the degree of light or temperature, movement of air or humidity irritates it and causes it to seek other appropriate resting-places. In the Jordan Valley, *A. sergenti* was noted to be hyper-excitable when flying near a DDT-sprayed surface, and to show a decided aversion to alighting on such sprayed surfaces. The absence of *A. sergenti* adults from DDT-sprayed premises does not thus necessarily mean effectiveness of the residual spraying. Unfortunately, the follow-up of *A. sergenti* adults caught in traps fixed to the windows of DDT-sprayed premises to get more accurate information as to the relative number of adults of this species which will enter sprayed premises has not been undertaken, and it is not known whether they remain for a sufficient time on sprayed walls to receive lethal doses of the insecticide.

Relation of *A. sergenti* to malaria. Wherever this species exists in its normal range of distribution it is considered an efficient malaria vector. Natural infection of this species in Palestine was reported in 1930 by Kligler in 195 mosquitos dissected.[l] In Egypt, an infected salivary-gland rate of 2.7% in 220 females of this species was obtained in the Inshass area along the eastern fringe of the Nile Delta.[m] In Jordan, the present author and J. M. Hadjinicolaou in 1954 found an infected salivary-gland rate of 1.4% among 500 *sergenti* dissected.

A. sergenti is considered the main autumn vector of *Plasmodium falciparum* in Israel, Jordan and the western Egyptian oases. In Egypt, the distribution of *A. sergenti* coincides exactly with the distribution of *P. malariae*, a fact which may be explained by its greater longevity in arid climates, not shared by the other indigenous malaria vector, *A. pharoensis*.[n]

Eradication of malaria transmitted by *A. sergenti*. The first disappointment regarding the effectiveness of DDT residual-spraying campaigns in controlling malaria transmitted by *A. sergenti* came from Jordan.[o] Observations made by the writer in the Jordan Valley during the period 1949 to 1952 inclusive showed that in spite of DDT-Gammexane residual spraying carried out twice in 1951, in April and August, in villages of the Jordan Valley, malaria transmission occurred in four out of twelve villages surveyed. In the north-eastern part of the valley, one round of DDT spraying effected in April 1952 did not protect the inhabitants, and in eight of the nine villages where a blood survey of infants was made during October and November of 1952, active malaria transmission had already occurred. The absence of *A. sergenti* in sprayed premises in the Jordan settlements, and the finding of them in big numbers in caves and fissures in neighbouring hills suggested an aversion of *A. sergenti* to sprayed walls. The occurrence of a malaria epidemic during 1952 in El-Gurm village (55.3% general parasite-rate, and 38% infant parasite-rate), where no adult *sergenti* could

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[l] Kligler, I. J. (1930) *The epidemiology and control of malaria in Palestine*, Chicago

[m] Farid, M. A. (1940) *Riv. Malar.*, 1, 159

[n] Bates, M. (1949) *The natural history of mosquitoes*, New York

[o] Farid, M. A. (1954) *Bull. Wld Hlth Org.*, 11, 765

be found in any of the premises sprayed in April of that year though they were abundant in the caves and fissures of the neighbouring hills, and the finding of one infective *sergenti* among those collected from the caves, led the writer to change the strategy of the antimalaria control operation in the Jordan Valley, and to make it dependent largely on antilarval measures.[p]

Saliternik voiced his doubts regarding the effectiveness of residual spraying in controlling malaria transmitted by *A. sergenti* by stating the following:

"Since 1945, when spraying of houses with DDT came into use, it was noted that while *A. sergenti* was affected as much as other species in the sprayed buildings, many of its normal resting sites were often in unsprayed sites such as caves, unfinished buildings, cellars, etc. Therefore to obtain a high degree of residual control the entire surroundings of settlements and villages in the malarial zones are sprayed. Current feeling in Israel, however, is that despite widespread residual spraying, no lessening of effort in larval control can be permitted." [q]

In the Dakhla and Kharga oases of Egypt, where *A. sergenti* is the main malaria vector, larvicidal measures, using 5% solution of technical grade DDT in solar oil to treat the breeding-places of both *A. sergenti* and *A. pharoensis* by means of the ordinary hand Flit-gun at a rate of 0.2 ml per m^2, led to the apparent eradication of *A. sergenti* but not of *A. pharoensis* in both oases after two years of intensive work (1946 and 1947). Although *A. sergenti* reappeared two years later, in a very limited area, malaria was almost eradicated, and the infant parasite-rate during 1949 was as low as 0.08%.

In the Siwa oasis in the north-western desert of Egypt, malaria was eradicated among the 4000 inhabitants after six rounds of DDT residual spraying made during a three-year period (1951 to 1953) and without any larval control. A pre-operational survey made in 1950 showed a malaria parasite-rate of 18% among 1000 inhabitants of all ages examined. In 1955, two years after cessation of residual spraying, the parasite-rate was zero among the 800 inhabitants examined.

In the Jordan Valley, antilarval measures, including the use of 3% DDT in solar oil to which 2% pine resin is added as a spreading agent, and applied weekly to all potential breeding-places in the Valley, have eliminated all malaria transmission. This operation however is costing 36 US cents per head whereas residual spraying used to cost only 12 US cents per head. The implementation of a larvicidal campaign has been necessitated by the special topography of the country, characterized by the weathered limestone hills with a multitude of fissures and caves, by the proximity of these hills to the villages, allowing adults of *A. sergenti* to seek refuge in more suitable daytime resting-places than the inside of the very hot, low-roofed rural structures, or the shaky and open, crude Bedouin hair tents. The Bedouins in Jordan are semi-nomadic; and during the dry season, which extends from March to November, they normally settle near valleys where there are springs or streams of water, usually teeming with an almost pure

[p] Farid, M. A. (1954) *Bull. Wld Hlth Org.*, 11, 765

[q] Saliternik, Z. (1955) *Bull. ent. Res.*, 46, 445

culture of *A. sergenti*. As these places are rather scattered and difficult to reach, there is a tendency to use a residual larvicide, applied once or twice during the year to deal with the *sergenti* breeding there. Trials with dieldrin wettable powder (250 g of dieldrin, 50% wettable powder per 10 l of water) sprayed at the rate of 0.25 g of technical dieldrin per square metre along the edges of the streams, including about one metre's breadth of the dry, sandy or gravelled shore as well as the dry surfaces of rocks sticking out of the water, the reeds and foliage along the shores, and any accessible, sizable natural caves existing in the valleys of these streams, have shown that one spraying eliminates all breeding of *A. sergenti* for 3-7 months. A list of the places sprayed in Jordan with such a dieldrin residual larvicide and the results obtained are shown below:

Place	Area sprayed (in m^2)	Date of spraying	Date of appearance of anopheline larvae	Period of residual effect
Fashkha swamp	150 000	25.3.55	20.10.55	7 months
Zor el Hamam	120 000	22.4.55	26.9.55	5 months
Ain Hamadam	6 000	22.4.55	14.7.55	3 months
El-Taybeh swamp	10 000	23.4.55	13.7.55	3 months
Ruseifeh and Zarka valley channels	97 300	8.6.55	negative on 10.10.55	> 4 months
Wadi Dahshah	65 750	14.6.55	negative on 10.10.55	> 4 months

It may be noted that no poisoning effect related to such residual larviciding was reported among the labourers applying it, or among the inhabitants or animals frequenting these water sources. The poisoning of a few goats and the destruction of beehives in one area were reported, but investigations showed that in the same area Folidol-E605, containing diethyl-paranitrophenyl thio-phosphate, had been extensively used in controlling agricultural pests.

Discussion. In many areas of *A. sergenti*'s range of distribution, malaria transmission due to this species can be eliminated by residual spraying alone, as has happened in Siwa Oasis. It is only in these hilly areas where semi-nomadic tribes are constantly moving towards the valleys during the drought season that *A. sergenti* has to be controlled effectively by larviciding to deal with the malaria problem.

In view of the accumulated facts that larviciding with chlorinated hydrocarbon insecticides enhances the development of resistance to these insecticides in the malaria vectors, this method is now looked upon with disfavour, and it is suggested that a return to Paris green or oil as larvicides should be made. Under these circumstances the larvicidal operation to eliminate malaria transmission brought about by *A. sergenti* will be handicapped, especially in remote valleys, because of the difficulty in reaching them, the absence of any accommodation for the labourers and their foremen, and the difficulty of supervising the work which has to be done repetitively every week during eight months of the year.

In Israel and Jordan, regular antilarval measures, including the draining, filling, flooding of stream beds and the use of oils, by themselves or in combination with other new organic insecticides, have been in use for some years against the aquatic stages of *A. sergenti*, since only partial control of malaria could be achieved by residual spraying alone. Information regarding the present status of the degree of resistance of *A. sergenti* in Jordan and Israel to chlorinated hydrocarbon insecticides is lacking, and presumably such a resistance may exist or may ultimately take place. Control of *A. sergenti* in rice fields in southern Syria by larviciding where the same topographical characteristics necessitating such measures exist as in Jordan and Israel has to be considered in the light of experience gained in both these countries, which has led to the prohibition of rice cultivation except under the most stringent restrictions.

If *A. sergenti* in both Jordan and Israel has already developed a fair degree of resistance to chlorinated hydrocarbon insecticides, especially to DDT or dieldrin, a resort to Paris green, to be used as a larvicide in the accessible and inhabited valleys, should be made. In remote and inaccessible valleys frequented by Bedouins, the use of a larvicide having a residual effect lasting at least three months has to be relied upon. The remote fear that *A. sergenti* from these places will develop resistance and become transplanted to areas where residual spraying against *sergenti* is still effective can be weighed against the greater risk of allowing this mosquito to maintain malaria transmission among the nomadic tribes capable of acting as *Plasmodium* carriers wherever they go. It is only when other malaria vectors such as *sacharovi*, *superpictus* or *pharoensis* breed in association with *sergenti*, that the development of resistant strains among these other vectors still vulnerable to DDT residual spraying should be prevented.

In view of the above facts, the following suggestions for dealing with the *sergenti* problem in an eradication programme are made:

In areas where malaria transmitted by *A. sergenti* can be stopped by residual spraying operations alone, this method should be used exclusively, and spraying should include not only living-quarters, but also all potential resting-places (unfinished buildings, store-rooms, ruins, underground cellars, etc.) within a radius of 6.5 km of the breeding-places. The timing of this spraying should be one month before the seasonal prevalence of *A. sergenti*.

In areas where malaria transmitted by *A. sergenti* cannot be totally eliminated by residual spraying campaigns alone, and where these areas are inhabited and easily accessible, and where *A. sergenti* breeds in association with other malaria vectors, antilarval measures should be confined to the use of Paris green or oils. If in these places *A. sergenti* breeds alone, and the results of susceptibility tests to chlorinated hydrocarbon insecticides show that its degree of resistance is still low, repetitive larviciding operations using oils in combination with any of the new organic insecticides may be permitted. In this case its degree of resistance should be followed up every year and might warrant a return to Paris green or oil.

In areas where *A. sergenti* is the main vector and does not breed with other malaria vectors, and especially where difficulties are experienced in reaching the breeding-places, accommodating the labourers, or maintaining frequent supervision of work, a residual larvicide with DDT or dieldrin could be applied as prescribed previously. The application can be made once or twice—the second spraying one month before the seasonal prevalence of *A. sergenti.*

Wherever malaria transmitted by *A. sergenti* cannot be stopped by DDT residual spraying operations alone, rice cultivation should be prohibited, as the expense involved in the control of this species by Paris green or oil would be too high, and the results would not be satisfactory for a malaria eradication programme. Such a ban on rice cultivation can be lifted when the objective of malaria eradication is reached. The use of chlorinated hydrocarbon insecticides in larviciding rice cultivations for the control of *A. sergenti,* either by ground or aerial methods, it to be condemned, as other malaria vectors still vulnerable to DDT residual spraying of houses co-exist with *sergenti* in these cultivations.

In places where it is feasible to supervise administration of antimalarial drugs for radical treatment and prophylaxis, or to indoctrinate the inhabitants in their regular use as a causal or clinical prophylactic, an attempt should be made in this direction, in combination with the antimosquito measures.

Susceptibility tests of *A. sergenti* to chlorinated hydrocarbon insecticides should be made regularly in the various countries where it is a principal malaria vector. The results of these tests should be correlated with the history of the use of these new organic insecticides, with the method of application of these insecticides, and with the dosages applied.

Implications of the Mecca Pilgrimage for a Regional Malaria Eradication Programme

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The Islamic faith demands that Moslems, at least once in their lives and provided they can do so, should perform the pilgrimage to Mecca and participate in the mass demonstration taking place every year on the ninth day of the month of Zulhidga (Arabic lunar calendar) and the following days. The date of the commencement of the pilgrimage is not fixed according to the Gregorian calendar, but falls each year on a date 11 days earlier than the preceding pilgrimage. Thus pilgrims are subjected, according to the date of the pilgrimage season, to a wide range of climatic conditions. As the large majority of these pilgrims are poor, or middle-class people, and as many of them are old and infirm, one can imagine the effect on them of a rigorous and strenuous trip, of the severe climatic conditions, and of the lack of environmental sanitation facilities. Even in the absence of epidemics, a high mortality rate is noted among them. In 1924, although