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OBSERVATIONS ON THE ETHIOPIAN ANOPHELINE MOSQUITOES AND THEIR SUSCEPTIBILITY TO INSECTICIDES

by

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The present paper deals with the bionomics, distribution etc... of the Ethiopian Anophaline mosquitoes and their susceptibility to the insecticides. The main observations on which this paper is based were made in the WHO Nazareth Pilot Project in 1958, in the ICA pilot projects (Kobo-Chercher plain, Dembia plain, Gambella area) and in many other areas of Ethiopia and Eritrea in 1959. Also, some previous observations of Italian, English and French workers concerning the bionomics were included when necessary. Most of these activities in 1959 were conducted in cooperation with Point Four Malaria Personnel who made the necessary arrangements to provide transportation for the various places visited inside Ethiopia and Eritrea.

I. OBSERVATIONS ON ETHIOPIAN ANOPHELES

Thirty-one different species of Anopheles have been reported up to now from the twelve different provinces of Ethiopia and from Eritrea. Some of these species are very rare and were never collected by the recent investigators from WHO or ICA. We mention below these rare species very briefly, as they may be encountered in future surveys. New species may be discovered in future, as some southern provinces such as Kaffa, Gemu Goffa, Sidamo and Harrar have been due to the lack of roads, superficially explored.

1. Anopheline species and malaria transmission

1.1 Anopheline species

The following 31 Anophelline species have so far been recorded:

A. coustani	A. leesoni	A. christyi
A. obscurus	A. funestus	A. cinereus
A. paludis	A. Harperi	A. turkhudi
A. implexus	A. longipalpis	A. rufipes
A. ardensis	A. marshalli	A. pretoriensis
A. kingi	A. rivulerum	A. maculipalpis
A. nili	A. wellcomei	A. dancalicus
A. rhodesiensis	A. demeilloni	A. pharoensis
A. rupicolus	A. garnhami	A. squamosus
A. adenensis	A. macmahoni	
A. d'thali	A. gambiae	

The data on their distribution by provinces are analysed in the Table I. This table shows that the main vector - A. gambiae is distributed all over the provinces and that A. funestus exists in six provinces. Other species, and secondary or suspected vectors, like A. pharoensis or A. pretoriensis are quite widely distributed. Others like A. rufipes are localised in one or two provinces. Among the other widely distributed species, A. coustani was collected in ten provinces and A. squamosus in eleven. A. nili, potential secondary vector, known only from Sidamo and Gemu Goffa, was found by us in Shoa and Ilubabor. A. d'thali and A. turkhudi, both species belonging to the Oriental Mediterranean region (Arabia, Persia, India, etc...) are mainly known from Eritrea and N.E. Ethiopia.

Other species, like A. garnhami, A. christyi, A. cinereus, are prevailing at high altitudes, though the last two can be found also in low lands. From Addis Ababa (2470-2600 metres), the following nine species have so far been reported: A. coustani, A. demeilloni, A. garnhami, A. macmahoni, A. gambiae, A. christyi, A. cinereus, A. pharoensis, A. squamosus. Careful investigations were undertaken, but up to now no breeding places have yet been found for three of these species, including A. gambiae (possibly imported) and the vector for the possible occurrence of autochtonous cases of malaria in Addis is still unknown. Breeding places occur in the lukewarm Filowa swamp (hot springs), Little Akaki River and Kabannah River. According to the precipitin tests most of the Anopheles seem engorged in Addis with animal blood (Ovazza & Neri, 1955). On the heights of Entotto (2800-3000m), A. cinereus was captured and seem to be the highest Anopheles in Ethiopia.

1.2 Malaria transmission

There is no doubt that the main malaria vector in Ethiopia is Anopheles gambiae, while A. funestus is locally important in the West (Gambella area), where it outnumbers A. gambiae almost all the year.

A. gambiae is widely distributed all over the 12 provinces of Ethiopia and in Eritrea, at altitudes below 2100m, where sufficient water is available for breeding. Large desert areas of lowlands in Harrar and Eritrea are relatively free of malaria (except the river valleys) because of the dry climatic conditions. This is the species responsible for the epidemics in the plateau. Where malaria is hyperendemic, i.e. wherever suitable breeding places exist all the year or for a sufficient period each year, A. gambiae is either the only vector or generally share with A. funestus the responsibility of the transmission.

A relatively limited number of dissections were made of the salivary glands of A. gambiae in the WHO and ICA projects. Few infected glands were found in the Nazareth area and in the Kobbo-Chercher project before or at the beginning of the spraying campaign. A sporozoite rate of 3% was found by the ICA team in Kobo-Chercher in September 1956.

A. funestus is too rare in some areas, like Sodore Hot Springs, to play an important part in the malaria transmission. However in Gambella, it is a very important vector.

Other species, A. pharoensis and A. pretoriensis, can be of possible importance in irrigated areas during the dry season when the A. gambiae populations are very low and the above mosquitoes very numerous. Sometimes, A. pharoensis can be the only mosquito present in the dwellings and it was found once infected by Ovazza in Ethiopia. Dissections of this species by the WHO team were always negative.

The status of other possible minor vectors such as A. nili, A. coustani var. ziemanni (1 specimen found positive for sporozoites in Ethiopia by Giaquinto), A. rufipes, Arhodesiensis, A. d'thali, A. kingi etc..., is still undetermined as no dissections appear to have been made anywhere in the country and the above species are rarely very aburdant. In Assab (Eritrea), A. adenensis is regarded by many authors as the local malaria carrier.

2. Bionomics of the vectors

2.1 A gambiae

This species is the most widely distributed and can be found everywhere in Ethiopia and Eritrea, temporarely or permanently, if there is any water available in the area. On the plateau, the breeding occurs in the temporary rainy pools and in the residual pools in the creeks before and after the rains. During the heavy rains the breeding places are flooded. All kind of breeding places, such as hoof prints even polluted with urine, side pools of river, shore of the lakes, (1) grassy swamps, cisterns etc... can be found. Permanent breeding occurs in the swamps issued from hot springs, (Sodore), irrigation ditches in the plantations (Alibete, Guibié etc.), permanent rivers (Awash, Omo), etc...

A. gambiae in Ethiopia seems under natural conditions highly anthropophilic, endophagic and endophilic, though it was found in many occasions to bite outside (Awash, Kobo-Chercher, Sodore, etc). Some specimens were found in Gambella town (sprayed) resting in outdoor shelters and on the northern shore of Margherita lake we found larval breeding at about 30km far from the nearest village: These mosquitoes were surely biting animals. In areas where men and animals (cows, horses) are mixed, the precipitin tests give a higher percentage positive for men than for animals. (2) In Sodore, in a man baited trap, at which a cow was tied outside; the results were 94% positive for men and 6% for animals. In Wonji, Ovazza (1956), and then the WHO team (1958) observed that the adults with numberous Culex are resting among the Sugar canes during day time near the breeding places, the irrigation ditches.

In the ICA projects (Alamata, Gambella), we found the mosquitoes resting in unsprayed dwellings and the sprayed ones without any Anopheles during day time, may be due to the repellent effect of the insecticide. Generally the A.gambiae are resting indoor down on the walls, driven away from the ceilings by the smoke. In dwellings where no cooking is made the gambiae are abundant everywhere on the ceilings and along the walls. The maximum collected by dwelling was more than 1.000 A.gambiae in an unsprayed tukul near Tesseneï in Eritrea.

In hyperendemic areas of Ethiopia, the mosquito fauna is subject to seasonal fluctuations. It must be a direct correlation between the river level, the rains, the pollution of the breeding places and the number and the species of adult mosquitoes. The predominence of A.funestus over gambiae is occurring in Gambella almost all over the year. Such a fluctuation is occurring in the permanent breeding places, like plantations (Wonji, Marti, Alibete, etc...) where A.pharoensis sometimes outnumber the A.gambiae. In the hot springs of Sodore, A.gambiae is however far away the most numerous, though A.pharoensis and A.coustani show some annual fluctuations.

In Sodoré Hot Springs (October 1958), the cycle of nocturnal activity of A. gambiae, i.e. the time frequency shown by the females in entering the man baited trap, is given below (average of two nights):

Hours	Number of females captured	%
16.00-20.00	144	37.8
20.00-24.00	185	48.6
24.00-04.00	33	8.6
04.00-08.00	18	4.7

The above results are a little different from those of other workers in that the maximum activity is between 6p.m. and 12.00p.m., instead of being spread over a larger period at a later hour after midnight but are not so different from those of Holstein. Few cases of day time biting have been recorded (Wonji Sugar Plantation, Akaki) and they are exceptional. In other areas where night catches have been conducted outdoors A. gambiae was found biting mainly after dusk and up to midnight. Some differences may occur on other parts of the country. Successful rearing of about seven generations of A. gambiae was realised in the Gambella ICA Pilot Project in an outdoor insectary.

There is no doubt that A. gambiae, due to its great adaptive power either in the choice of the breeding places, or the source of blood for adults, is the main malaria vector in all parts of Ethiopia.

2.2 A. funestus

Though A. funestus can be collected in six provinces (Shoa, Gogiam, Wollega, Illubabor, Kaffa, Harrar) and in Eritrea, generally in low lands (not above 1.700m), this species is generally scarce. It seems by its abundance to share the responsibility of malaria transmissions with A. gambiae only along the Baro River, in West (Gambella area).

Because of its predilection for breeding in permanent waters, A. funestus is practically absent from the plateau and always associated with malaria in endemicity and not with epidemics. In Gambella, it is breeding in the grassy swamps and predominant over A. gambiae in the adults stage, almost all over the year. In Sodore, it seems to breed in the permanent Swamps issued from the hot springs, but there, no more than two-three specimens were collected every month.

Adults are generally very endophilic and anthropophilic. However they can bite men also outside with A. gambiae after dusk. Only one specimen was captured in outdoor shelters in Gambella, but few investigations were undertaken and only during the rainy season when the river banks are wet and without crevices. In Gambella town, after the first spraying with DDT in 1959, A. funestus disappeared completely from the sprayed dwellings but was captured in a very small number from unsprayed dwellings. In one unsprayed tukul, at about 5km from the town, we captured in August 1959 287 A. funestus and 63 A. gambiae. A. funestus as A. gambiae are resting down on the walls, mainly if the hut is filled with smoke, otherwise they can be found on the ceilings. As A. gambiae, A. funestus is strongly attracted by unwashed clothing in the native huts, and frequently resting behind. In the month of August 1959 (rainy season) our five day collections gave the following percentage in Gambella area: A. funestus 80%, A. gambiae 17%, A. pharoensis 1%, A. nili 0.01%, thus showing strong predominance of A. funestus. In February fifty-nine (dry season) five day collection gave: 50% A. funestus against 41% A. gambiae. Perhaps the number of A. gambiae increase when the

swamps are polluted and become more favourable to its larvae. This should be investigated.

It is possible that in other areas (Omo Valley, Keffa etc...) A. funestus which is closely associated with A. gambiae play also an important part in the malaria transmission. Investigations have still to be carried out in those areas.

2.3 Other suspected vectors.

a) A. pharoensis

This species (found once infected in Ethiopia by Ovazza) is the most common mosquito after A. gambiae, during some months of the dry season, when A. gambiae becomes scarce. It has been captured in eight provinces and in Eritrea, and seems even more widely distributed from lowlands up to the high plateau (2.500m). It is a very common species in irrigated areas (plantations of Marti, Shoa; Wonji, Shoa; Tessenei, Eritrea; Ghibié, Kaffa etc...). In Gambolla, it is a rather rare mosquito.

The larva breeds in various collections of water, but are very common in irrigation ditches (plantations) permanent swamps resulting from hot springs (Sodore, Koka dam), on the edges of the lakes even in flooded areas at the end of the rains (Koka village).

In Ethiopia, the adults seem to be anthropophilic and endophilic, but commonly bite man outside during the night. Few precipitin tests have been made and thus are insignificant. Ovazza (1956) found that species exophilic below 1.900m in Ethiopia, but our findings are quite different. We found even in low areas (Marti, 948m) this species extremely abundant in the human dwellings (June 1958) during day time, and this observation was confirmed in Koka (1.530), Wonji (1.650ms) and even in Gambella (526m). Some outdoor shelters can be found but are not so common. It does not seem that Ovazza is right when he estimated that A. pharoensis became predominant in Wonji "que lorsque A. gambiae fut en partie éliminé par la forte lutte anti-larvaire et anti-adultes pratiquée en 1954". On the contrary, A. gambiae is still very abundant in the unsprayed dwellings in the surrounding native huts but the abundance of A. pharoensis is only a seasonal one.

In conclusion, in Ethiopia, A. pharoensis shelter in huts during the day and when the breeding is prolific there is an overflow into human dwellings. Its maximum peaks of entry into a hut seems to be between 8 p.m. and 12 p.m. The results obtained in Sodore experimental trap (October 1958) are grouped below (average of two nights):

Hours	Number of females captured	%
18.00-20.00	23	31
20.00-24.00	44	59.4
24.00-04.00	3	4
04.00-08.00	4	5.4

The above findings are similar to the figures obtained there for A. gambiae.

Corradetti considers A. pharoensis as "one of the most dangerous carriers of malaria in Ethiopia". Practically, due to its low infectivity, the mosquito can play, when very abundant, a possible small part in the transmission.

b) A. rufipes

This species is known only from Wollo and Illubabor (Gambella). In Gambella its presence seems to coincide with the drying of the grassy swamps. Rare and of a little importance, if any. Adults were collected indoors in Gambella.

c) A. pretoriensis

In Ethiopia, this species is regarded by some workers as an important vector but no evidence has so far been recorded. This species is widely distributed from lowlands up to 1.900m in eight provinces and in Eritrea, but rarely very abundant. This species was collected from the three ICA projects, but very exceptionally from the WHO project. It breeds in drying river pools.

d) A. adenensis

This species is considered by all authors to be the malaria carrier in Assab (Eritrea), but there is no definite evidence on this. This mosquito breeds with Culex sitiens in the wells and cisterns of the town, in water containing up to 70% sea water and nitrates.

e) A. coustani

This species with its two varieties tenebrosus and ziemanni is widespread over practically the whole of Ethiopia though it has not been yet recorded from Gamu Gofa and Wellega but it must be existing there also. In Eritrea, A. coustani is mainly reported from Tesserei (Sudanese border). This species is common up to 2,100m (Akaki) but can be exceptionally captured higher (Addis, 2,470m).

The larval breeding occurs mainly in the swamps, back-waters of streams and irrigation ditches in plantations (Wonji, Ghibié). The adult seems partly anthropophilic and can be exceptionally found inside houses during day time (Metahara, Sodore, etc...). It bites outdoors and even, when exceptionally abundant and disturbed, during day time in the afternoon: Wollo (Ovazza, 1956); Sodore (WHO Team) where the adults rest among the grass of the swamp.

Giaquinto (1950) who found one ziemanni in Borkenna valley (1.796m) positive for sporozoites suspected that variety as a vector. It seems however to be a non vector or at least to have no importance. As in other parts of Africa, A.coustani seems attracted by the light inside the houses, rather than by the prospect of biting men.

f) A. nili

A. nili was only known from Southern Ethiopia (Billate River, Sidamo prov., 1.200m and Valley of Sagan River, Gemu Goffa prov., 1.400m). We found specimens (1 or 2 per month) in Sodore (Shoa, 1.600m) in 1958, in similar conditions than in Billate. The breeding in these two places seems to occur in swamps near hot springs. In Gambella (August 1959), we found some A. nili resting indoors as in Sodore, thus this species seems to be partly endophilic. In the Sagan Valley (Giaquinto, 1948), hundreds of specimens attacked the men severely in the open and in the tents, being there the prevailing species.

Except for the above observations, and despite its possibility as a vector, A. nili, cannot be considered to be of importance in Ethiopia because of its rarity when compared with the main vectors.

g) Other Ethiopian Anopheles

Among the other Ethiopian Anophelines, certain species are only rarities (A. obscurus, A. paludis, A. implexus, A. ardensis, A. rupicolus, A. harperi, A. longipalpis, A. rivulorum, A.leesoni, A. wellcomei, A. maculipalpis) and they can be considered as harmless in Ethiopia. Their distribution by provinces is shown in the Table I. A. kingi was reported to be sometimes quite common and to attack men in the open (Kaffa, Sidamo), but does not seem to be a vector, since A. gambiae was obviously present wherever malaria occurred (Giaquinto, 1950). A. rhodesiensis is considered by Giaquinto (1950) as a malaria carrier in Ethiopia, but it is doubtful. This species is known from Harrar, Wollo, Beghemder and Eritrea and attacks severely men in the open in eastern Ethiopia (Ogaden, Dankalia)

Some other species, not malaria carriers are quite common in some areas: A.d'thali collected in six provinces, is mainly common in Eritrea below 1500m and in the eastern side of Ethiopia. According to Mara (1946) the various breeding places are exposed to sunlight and the larvae can be found in water with salinities of 3.5% in association with those of A. dancalicus. This species rather rarely found in human dwellings cannot be considered as vector, though it was the opinion of Bambilla (1941), Lega (1937), Melville (1945) and Mara (1946). No dissections have been made anywhere and A. gambiae is often present in the same area.

A. marshalli is an exophilic and mainly zoophilic mosquito, captured in Ethiopia in mule stables and pig-sties. Larvae in marshes, even with brackish water and in torrents. Adult females attacked men in the open in Gumma (Giaquinto, 1950). Recorded from five Ethiopian provinces, but not from Eritrea.

A. demeilloni: Reported in seven provinces and in Eritrea from low lands up to 2550m. Larvae and adults in Addis Ababa. Larval breeding in all kinds of water collections, even in drying river beds. Common species in the ICA projects of Kobbo-Chercher and Dembia. Not reported from Gambella and Nazareth projects. Generally exophilic and zoophilic sometimes captured in human dwellings.

A. turkhudi: Reported from Eritrea and north-eastern Ethiopia, in low lands. This asiatic species is quite rare and not a malaria carrier.

Some species can be found indifferently in low lands and in low plateau: A.macmahoni (up to 2400m), A.cinereus (up to 3000m in Entotto and Termaber Pass), A. squamosus (up to 2400m). Two other common species are almost restricted to high altitudes in Ethiopia: A.garnhami and A.christyi (up to 2800m) but can be also exceptionally found in low areas. These species are mainly zoophilic, exophilic or resting in cattle sheds and cannot be malaria carriers. If resting in human dwellings, they are unfed or fed with animal blood.

The only Ethiopian indigenous species is Anopheles dancalicus, described by Coradetti in 1940, from Dobi Valley, Wollo (250m, in Dankalia area). The larval breeding places are small pools encrusted with salt and salty marshes with vegetation. The species is exophilic and attacks men in the open. It is also recorded by Mara from other localities or the Dankalia area (Arafali, 161m, Laile etc...) in the lowlands. A. dancalicus is not a malaria carrier.

Since new species of Anophelines have been recently recorded from Somalia (Maffi, 1958), it seems that other species may be discovered when the Harrar province will be better explored.

II. SUSCEPTIBILITY OF ADULT ANOPHELES MOSQUITOES TO INSECTICIDES IN ETHIOPIA

Since March 1958, thirty-seven susceptibility tests of adult Anopheles to DDT and Dieldrin were carried out in Ethiopia and in Eritrea. Three species of mosquitoes were tested: A. gambiae A. funestus, A. pharoensis, i.e. the three local vectors. Attempts to test other non-vector species were unsuccessful due to the scarcity of specimens captured. Even A.coustani in Shoa and A. squamosus in Eritrea, which can be extremely abundant in certain years, were never collected in more than 5-10 specimens in the same area.

Results so far obtained are included in the two annexed Charts (Table II and III), which show the LC_{50}s. Mortalities at high concentrations the LC_{100}s can be deducted by interpolation.

1) Techniques

In all cases, engorged wild caught females were only tested. The tests carried out at the beginning (from March to June 1958) following the method of Busvine & Nash. Later, since July 1958, the standard WHO test kits were used exclusively. Similar results are given with this new test, as those given by the Busvine-Nash tests, and the differences, if any, are insignificant.

Different methods were used to transport the mosquitoes for testing in the laboratory, but in order to avoid high control mortality, whenever possible, tests were made in the field. In Tessenei, Eritrea, and in few other places, we could not avoid, during the recovery period, extremes of temperature (up to 35°C) and thus the testing became extremely difficult and some of the experiments were lost completely. In Gambella, we were able to use the local insectary, so the results were very satisfactory with extremely low mortalities in the control.

Extreme care was taken when transporting the mosquitoes to avoid insecticide contamination. In Nazareth project the same vehicles were used for the spraying and the entomological work, and thus a careful washing of the vehicles was periodically done.

In Ethiopia, the permanent breeding places (Gambella, Sodore, Awasa, Awah, Marti, Ghibié etc...) are rare and nine months of the year are comparatively dry. So it is quite impossible to find enough mosquitoes in most of the areas except during one or two months, sometimes durin two weeks. One never can be sure of the right time for collecting the season being more or less rainy in an area, or the breeding places being washed out by abnormally abundant rains. Most of the testings should be done at the same time in all the country usually after the rains, and in Eritrea it is even more restricted in time. Due to the previous reasons and also because not enough time could be always devoted to the testing work, some first tests (mainly Busvine) should be interpreted as unsatisfactory according to the most recent WHO instructions (as few mosquitoes were exposed to each concentration). All details can be seen from the accompanying charts. We discarded only the tests with a too high control mortality but we kept a complete record of the others, even if some should be accepted with reserve. At least they give an indication, practically confirmed by the other satisfactory reliable tests.

The LC_{50}s have been calculated (on the corrected mortalities if necessary) from which the regression lines have been fitted by eye on logarithmic probability paper.

2. Results of susceptibility tests in unsprayed area:

a) A. gambiae

In the unsprayed Awash area (Shoa), Busvine susceptibility tests gave in March-April 1958, very high susceptibilities of A. gambiae to DDT (LC_{50} = 0.32%) and the Dieldrin (LC_{50} = 0.022%). Similar results with very high susceptibilities to both insecticides, were obtained in the unsprayed area between Nazareth and Wonji (DDT, LC_{50} - between 0.15% and 0.48%; Dieldrin, LC_{50}- between 0.025% and 0.047%). Such results, similar to those obtained with Busvine method in few localities of West Africa in 1957 (Cameroons, Haute Volta) should be considered as exceptional for A. gambiae.

In other unsprayed areas, the LC_{50}s are much higher and can be considered as normal (WHO method):

Gambella (Ilubabor): DDT LC_{50} = 0.64% Dieldrin LC_{50} = 0.042%

Ghibié (Kaffa): DDT LC_{50} = 0.70% Dieldrin LC_{50} < 0.06%

Gouche (Sidamo): DDT LC_{50} = 0.72%

In the above cases, the indicated LC_{100}s were always 4% for DDT and 0.4% for Dieldrin. In the case of Ghibie (4% DDT: 53 tested, 1 alive), the population seems highly susceptible and the one which escaped the highest concentration is probably a random survivor. The above tests gave an idea of the baseline of susceptibility for A. gambiae in Ethiopia before spraying activities.

b) A. funestus

Tested in Gambella, before the spraying of the town, A. funestus show normal susceptibility (Feb. 1959): DDT LC_{50} = 0.54%; Dieldrin: LC_{50} = 0.045%. After spraying, the mosquitoes were collected 5Km away in an unsprayed village (August 1959) and when tested the LD_{50}s were for DDT = 0.72% and for Dieldrin = 0.082%. This slight increase in the susceptibility seems to be only a seasonal variation. A complete kill is given as for A. gambiae at 4% DDT and 0.4% Dieldrin (indicated LC_{100}).

c) A. pharoensis

A. pharoensis in an unsprayed area (Marti, near Metahara) showed in 1959 an LC_{50} below 0.15% for Dieldrin which is a normal value for that Anopheles.

3. Results of susceptibility tests in sprayed areas

a) A.gambiae

In the sprayed areas, tested with WHO Method, A.gambiae shows also a high susceptibility to the insecticides. LC_{50} levels in several places in Ethiopia and Eritrea lie between below 0.25% and 0.70% for DDT and between 0.04% and 0.063% for Dieldrin.

In Sodore, sprayed once with DDT, there is a little variation according to the date of the testing: LC_{50}s between 0.51% and 0.70% DDT and between 0.054% and 0.06% Dieldrin. Perhaps it is connected with the flooding or variations in organic matter content of breeding places, or with the temperature (much lower during the night when we got the higher susceptibilities):

Tests carried out in the Nazareth pilot project gave a DDT LC_{50} of 0.42% and a Dieldrin LC_{50} of 0.063% (Koka village sprayed twice with DDT).

In Wassero (Awash area) where the breeding places (irrigation ditches) produce their anopheline fauna all the year round, the following LC_{50}s were found after the first spraying with Dieldrin - DDT_{50} = 0.62%; Dieldrin LC_{50} = 0.06%. So a single spraying with Dieldrin in May 1958 (testing done in April 1959) seems to have increased the LC_{50} of A.gambiae from 0.32% up to 0.62% for DDT and from 0.022% up to 0.06% for Dieldrin.

The increase of tolerance can be only due to the elimination of the more susceptible phenotypes but in both cases the LC_{100}s were respectively at 4% DDT and at 0.4% Dieldrin (165 specimens were exposed to 4% DDT and 256 to 0.4% Dieldrin). This does not seem to indicate the presence of a factor for true DDT or Dieldrin resistance.

In other areas, the following LC_{50}s were found:

Kombolcha (Nazareth project-sprayed DDT'58): DDT: 0.36%

Alamata (ICA Kobbo-Chercher project-sprayed Dieldrin'56;DDT'57-58-59): DDT <0.25% Dieldrin: 0.04%.

Ali Geder (Eritrea, cotton crops sprayed by plane with BHC/DDT during four years): DDT:0.60% Dieldrin: 0.06%.

The spraying of those areas seems not to have increased the tolerance of A.gambiae. In the above cases the mosquitoes have been collected from unsprayed dwellings among the sprayed ones. The extremely low DDT LC_{50} in Alamata is associated with a comparatively high control mortality and further tests are needed.

b) A.pharoensis

The following LC_{50}s were obtained in sprayed areas:

DDT: 0.71% (Koka-sprayed two times with DDT); 0.34% (Kedamegebaye-sprayed once with DDT)

Dieldrin: 0.1% (Koka)

No indication of tolerance can be found from the above results.

4. Conclusion

a) The three species tested to insecticides (A.gambiae, A.funestus, A.pharoensis) are extremely susceptible to DDT and Dieldrin in the unsprayed areas and normally susceptible in the sprayed ones, even after 3-4 years spraying.

b) There is no indication of real tolerance, or at least no significant change of susceptibility in the Pilot projects up to now. It is too early to think that A.gambiae in Awash area has developed a real increase of tolerance to Dieldrin after the first spraying with this insecticide.

c) It seems that the most probable areas where resistance could be established (if the resistant genotypes preexist) are the permanent breeding areas (Gambella, Awash) in the low lands where many generations occur all the year. On the plateau, the speed of selection of a resistant strain will be slow (few annual generations).

d) A.pharoensis seems to be normally a little less susceptible to the insecticides than A.gambiae, smaller sized mosquito, A.funestus shows a similar susceptibility as A.gambiae.

e) There is an indication of seasonal variation in the LC_{50}s according to the month of the testing but this variation is very low.

f) In Addis Ababa, there evidently preexists a considerable degree of natural tolerance with DDT (LC_{50} = 3.2) and Dieldrin (LC_{50} = 0.92) in the adults of Culex pipiens. The highest concentrations of DDT and of Dieldrin fail to give more than 61% mortality for DDT and 58% for Dieldrin with one hour exposure. Such results were never found among the Ethiopian Anopheles.

TABLE I

Anopheles Distribution in Ethiopia

Provinces: / species A.	coustani	obscurus	paludis	implexus	ardensis	kingi	nili	rhodesiensis	rupicolus	adenensis	d'thali	leesoni	funestus	harperi	longipalpis	marshalli
Shoa	x						x		x		x		x			
Gojjam	x												x			
Wollega													x			
Ilubabor	x						x						x			
Kaffa	x			x		x							x			x
Gamu Gofa							x									
Arussi	x															
Harrar	x							x	x		x		x			
Wollo	x		x					x			x				x	x
Tigre	x								x		x					x
Beghemdir	x							x	x					x	x	x
Sidamo	x	x			x	x	x				x	x				x
Eritrea	x							x		x	x		x			

Provinces: / species A.	rivulorum	wellcomei	demeilloni	garnhami	macmahoni	gambiae	christyi	cinereus	turkhudi	rufipes	pretoriensis	maculipalpis	dancalicus	pharoensis	squamosus
Shoa			x	x	x	x	x	x			x			x	x
Gojjam			x			x	x							x	x
Wollega			x			x					x				
Ilubabor		x				x				x	x			x	
Kaffa			x	x		x	x	x			x				x
Gamu Gofa						x					x				x
Arussi						x								x	x
Harrar	x		x	x	x	x	x	x	x		x			x	x
Wollo			x	x	x	x	x	x		x	x		x	x	x
Tigre						x		x							x
Beghemdir				x	x	x	x	x	x		x			x	x
Sidamo			x	x	x	x					x	x		x	x
Eritrea			x		x	x		x	x		x		x	x	x

Species	Province	Village	Spray Record	Date	Temp. ♂	♀
A. gambiae	Shoa	Wassera	unsprayed	19-20/III/58	29.5	
A. gambiae	Shoa	Kedamu-Gebeya	unsprayed	30/III-6/IV/58	28	
A. gambiae	Shoa	Kombolcha	unsprayed	31/III-6/IV/58	28.5	
A. gambiae	Shoa	Adamkata	unsprayed	3/IV/58	27	
A. gambiae	Illubabor	Gambella	unsprayed	[illegible]	38	
A. gambiae	Kaffa	Shishiè	unsprayed	[illegible]	32	
A. gambiae	Sidamo	Orocha near Bale	unsprayed	[illegible]	19	
A. gambiae	Shoa	Sodere	DDT 1957	[illegible]	22	
A. gambiae	Shoa	Koka	DDT 57-58	[illegible]	26	
A. gambiae	Shoa	Koka	DDT 57-58	[illegible]	25	
A. gambiae	Shoa	Kombolcha	DDT 1956	[illegible]	22	
A. gambiae	Shoa	Sodere	DDT 1957	5/V/58	25	
A. gambiae	Shoa	Wassera	Dieldrin 58	[illegible]	24	
A. gambiae	Wollo	Alamata	Dl.56-DDT 57-58-59.	[illegible]	25	
A. gambiae	Eritrea	Ali Gader	4 years aerial spray DDT EEC	[illegible]	32	
A. pharoensis	Shoa	Koka	DDT 57-58	3-6/IX/58	25	
A. pharoensis	Shoa	Kedamu Gebeya	DDT 1958	7-9/X/58	27	
A. funestus	Illubabor	Gambella	unsprayed	10-13/IX/58	38	
A. funestus	Illubabor	Gambella	unsprayed	30-31/VIII/58	23	

TABLE II

Rel. Hum. %	Method	0.1% No. Tested	0.1% Dead	0.1% Observed Mort. %	0.25% No. Tested	0.25% Dead	0.25% Observed Mort. %	[illegible]
45	Busvine	9	2	22.2	22	10	45.4	
93	Busvine	61	10	16.4	61	27	27.5	
90	Busvine	48	18	37.5	44	28	63.6	
92	Busvine	21	8	38.1	31	24	77.4	
89	WHO				52	9	17.3	
41	WHO				29	5	17.2	
91	WHO				24	15	62.8	
83	WHO				31	2	6.4	
61	WHO				40	19	47.5	
70	WHO				84	24	27.3	
58	WHO				22	9	40.9	
84	WHO				93	16	17.2	
50	WHO				78	26	37.9	
70	WHO				40	25	62.5	
62	WHO				70	24	34.2	
90	WHO				50	2	4	
59	WHO				146	48	37.7	
27	WHO				189	27	14.2	
92	WHO				78	6	7.6	

SUSCEPTIBILITY TESTS

0.5%		0.75%				
No. Tested	Dead	Observed Mort. %	No. Tested	Dead	Observed Mort. %	No. Tested
20	12	60				20
76	30	38.1	61	44	72.1	63
55	47	85.4	67	66	98.5	60
31	25	80.6	33	33	100	31
45	25	57				44
22	5	22.7				40
17	6	35.2				16
62	18	29.5				60
60	38	63.3				57
38	30	78.9				43
23	13	56.5				45
89	40	44.9				114
50	17	32				60
43	33	76.7				46
76	34	44.7				72
37	7	18.9				48
132	96	72.2				342
185	44	38.2				70
70	18	25.7				69

TABLE I

Rel. Hum. %	Method	0.1% No. Tested	0.1% Dead	0.1% Observed Mort. %	0.25% No. Tested	0.25% Dead	0.25% Observed Mort. %
45	Busvine	9	2	22.2	22	10	45.4
93	Busvine	61	10	16.4	61	17	27.5
90	Busvine	48	18	37.5	44	28	63.6
92	Busvine	21	8	38.1	31	24	77.4
27	WHO				52	9	17.3
41	WHO				29	5	17.2
91	WHO				24	5	20.8
83	WHO				31	2	6.4
61	WHO				40	19	47.5
70	WHO				84	24	27.3
58	WHO				22	9	40.9
84	WHO				93	16	17.2
50	WHO				78	14	17.9
70	WHO				40	25	62.5
62	WHO				70	24	34.2
70	WHO				50	2	4
59	WHO				146	40	37.7
27	WHO				189	27	14.2
92	WHO				78	6	7.6

Species	Province	Village	Spray Record	Date	Temp. C
A. gambiae	Shoa	Wassero	unsprayed	19-20/III/58	29.5
A. gambiae	Shoa	Kedame-Gebaye	unsprayed	30/III-8/IV/58	28
A. gambiae	Shoa	Kombolcha	unsprayed	31/III-9/IV/58	28.5
A. gambiae	Shoa	Adankata	unsprayed	3/IV/58	27
A. gambiae	Ilubabor	Gambella	unsprayed	10-13/II/59	38
A. gambiae	Keffa	Ghibidè	unsprayed	4-6/VI/59	32
A. gambiae	Sidamo	Gruche near Boke	unsprayed	10/VI/59	19
A. gambiae	Shoa	Sedore	DDT 1957	28/VII-2/VIII/58	22
A. gambiae	Shoa	Koka	DDT 57-58	26-28/VII/58	26
A. gambiae	Shoa	Koka	DDT 57-58	3-6/III/58	25
A. gambiae	Shoa	Kombolcha	DDT 1958	23-27/III/58	22
A. gambiae	Shoa	Sedore	DDT 1957	5/I/59	25
A. gambiae	Shoa	Wassero	Dieldrin 58	25-27/IV/59	34
A. gambiae	Wollo	Alamata	Dl.56-DDT 57-58-59.	11-12/II/59	25
A. gambiae	Eritrea	Ali Geder	4 years aerial spray DDT	29-31/IX/59	32
A. pharoensis	Shoa	Koka	DDT 57-58	3-6/III/58	25
A. pharoensis	Shoa	Kedame Gebaye	DDT 1958	7-9/I/58	27
A. funestus	Ilubabor	Gambella	unsprayed	10-13/II/59	38
A. funestus	Ilubabor	Gambella	unsprayed	20-24/VIII/59	23

R A T I O N I N M I N E R A L O I L

Control			Dieldrin	
Observed Mort. %	No. Tested	Dead	Observed Mort. %	LC_{50}
100	27	0	0	0.022
	67	1	1.4	0.027
	67	1	1.4	0.025
	27	2	7.4	0.025
	66.	2	3.	0.042
100	53	0	0	< 0.06
100	74	3	4	< 0.06
100	24	2	8.3	0.063
100	114	6	5.2	0.054
100	95	3	3.1	0.06
100	25	2	8.	0.04
98*	10	10	100	0.06
	23	1	4.3	< 0.15
100	27	0	0	0.1
	61	0	0	0.045
100	199	6	3.8	0.082

* tested - 84 dead; with 1 76 tested - 76 dead.

				D I E L D R I N C O N C E N				
		0.1%			0.2%			0.4%
Observed Mort. %	No. Tested	Dead	Observed Mort. %	No. Tested	Dead	Observed Mort. %	No. Tested	Dead
74	34	31	91	34	34	100	32	32
58.3	65	60	92.3	55	54	98.2		
73.1	57	56	98.4	35	35	100		
92	23	22	97.4					
31.6	18	17	94.4	23	22	95.7		
0	83	70	84.3	27	25	92.5	57	57
32.6	86	65	75.5	69	66	96.4	24	24
36.8	30	25	76.6	32	31	96.8	43	43
38.7	72	49	68	98	88	95.6	75	75
31.8	138	139	86.2	225	222	98.6	256	256
62.8	36	31	86.1	46	45	97.8	100	100
41.6	76	52	68.4	100	96	96	102	100
18.9 mm								
19.3	34	16	42	28	27	93.3	35	35
56.8	43	38	88.8	75	71	97.2		
20.2	69	30	44	48	57	98.4	137	137

s Testmade with 0.8% D1 gave the following results

mm Corrected.

TABLE III - SUSCEPTIBILITY TESTS

REL. HUM. %	METHOD	0.01%			0.025%			0.05%	
		No. Tested	Dead	Observed Mort. %	No. Tested	Dead	Observed Mort. %	No. Tested	Dead
72	Busvine				28	16	57.1	27	20
85	Busvine	26	5	19.2	65	33	50.7	60	35
63	Busvine	31	10	32.2	59	19	32.2	93	68
85	Busvine	20	2	10	24	18	75	25	23
29	WHO				24	10	41.6	19	6
41	WHO				6	0	0	33	0
63	WHO	89	6	6.7	97	11	11.3	60	10
70	WHO				12	0	0	38	14
85	WHO				25	6	24	62	24
50	WHO				174	22	12.6	159	90
70	WHO				42	17	40.4	95	82
62	WHO				84	26	30.9	72	30
90	Busvine	18	2	11.1	18	3	16.6	16	3
70	WHO				17	0	6	31	6
27	WHO				52	10	19.2	44	25
92	WHO				70	7	10	79	16

4 dea. 50% mort.

SPECIES	PROVINCE	VILLAGE	SPRAY RECORD	DATE	TEMP. °C
A. gambiae	Shoa	Wassero	Unsprayed	19-20/III/58	28.5
A. gambiae	Shoa	Kedamo gebeya	Unsprayed	8/IV/58	28
A. gambiae	Shoa	Komboloha	Unsprayed	31/III-1/IV/58	25.5
A. gambiae	Shoa	Ansankuta	Unsprayed	3/IV/58	28
A. gambiae	Illubabor	Gambella	Unsprayed	11-13/II/59	30
A. gambiae	Keffa	Ghibie	Unsprayed	4-6/IV/59	32
A. gambiae	Shoa	Sodore	DDT 1957	20/VIII/58	20
A. gambiae	Shoa	Koka	DDT 57-58	3-6/IX/58	25
A. gambiae	Shoa	Sodore	DDT 1957	8/I/59	26
A. gambiae	Shoa	Wassero	Dieldrin 1958	26-27/IV/59	34
A. gambiae	Wollo	Alamata.	Dl.56 DDT 57.58-59	11-12/II/59	25
A. gambiae	Eritrea	Ali geder	aerial spray DDT-BHC	19-21/II/59	22
A. pharoensis	Shoa	Marti	Unsprayed	22-23/V/58	25
A. pharoensis	Shoa	Koka	DDT- 57-58	3-4/IX/58	23
A. fumestus	Illubabor	Gambella	Unsprayed	12-12/II/59	30
A. fumestus	Illubabor	Gambella	Unsprayed	20-24/VIII/59	29

xx Test made with Dieldrin concentration 0.075 gave the following results: 8 test