MALARIA CONTROL BY AIRCRAFT SPRAYING OF PARIS GREEN WITH SPECIAL REFERENCE TO WARTIME EXPERIENCE IN EGYPT.

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In 1942 in Egypt a vital Royal Air Force aerodrome suffered heavily from malaria. The aerodrome had been necessarily sited beside a swampy lake, near a large native village in a highly malarious area. So that its work could be carried on, maintenance crews had to be imported from other units.

In 1943 an antimalarial control unit (A.M.C.U.) commanded by an entomologist, Flying Officer Redmond King, was attached to the station, and as part of the control an aeroplane was used to spray Paris Green over the lake. At the end of the season the malarial incidence was one third of that of the preceeding year, and much valuable experience had been gained.

The writer was posted as senior medical officer of the station early in 1944, and in the absence of an officer commanding the A.M.C.U., had charge of the malaria control. This thesis is based on his experience of aircraft spraying in the 1944 season.

A few historical facts leading up to the present paper may interest the reader. Barber and Hayne (1921) first demonstrated the value of Paris Green as a larvicide. In the following year Neillie and Houser (1922) dusted a catalpa grove of five thousand trees, with lead arsenate from an aeroplane, and controlled an outbreak of the catalpa sphinx, a large moth in the adult stage, which would otherwise have ruined much valuable timber. Coad et al (1924) applied this technique against cotton pests. Hard on their heels, King and Bradley (1926) commenced experiments of the control of Anopheline larvae by dusting Paris Green from an aeroplane, and Williams and Cook (1927 and 1928) used this method successfully in malaria control at the United States naval base of Quantico, Virginia.

Outside America, work in this field was being carried out in Madagascar by Legendre (1934) who sprayed ricefields and a marsh near a French Air Force station. In India, Covell and Afridi (1937) had experimented with this form of malaria control, but found it unlikely to prove of practical value in the existing circumstance in that country.

Meanwhile, American workers (Watson 1936, then Watson et al 1938, and Kiker et al 1938), after due experimentation applied aircraft spraying when the impounding of the Tennessee River by the Tennessee Valley Authority created large expanses of water presenting ideal breeding condition for mosquitoes, out of small natural collections of water. They used an aircraft belonging to the authority and also a plane hired from a crop dusting contractor.

More recently Murray and Knutson (1944) used the aircraft of a commercial crop dusting company for malaria control on the Potomac River and achieved great success.

A DESCRIPTION OF THE AREA AND ITS WEATHER.

Our aerodrome was situated on a narrow strip of sandy country, about two kilometers wide, between the Mediterranean Sea to the north and a lake to the south. Between and bordering the camp and the lake were a road and railway running side by side. The site was flat and low lying, being only 18 inches above sea level.

Cultivation was negligible in the area. There were a few date palm plantations in the vicinity of the camp and tomatoes were also grown nearby. These depended on subsoil water.

A few hundred natives lived in small groups of huts round the camp. Apart from these the local population was centred in a very large village beginning 2 miles from the east end of the aerodrome. This village had a static population of 26,000 crowded into miserably poor dwellings. The people were poor and lived chiefly by fishing in the lake and in the sea.

The malaria season in Egypt lasts nominally from April 1st to 30th November. The writer observed the weather during the 1944 season and noted the following. A cool northwesterly or northerly wind from the sea prevailed. This wind for most of the season had a speed from 15 - 18 miles per hour after ten o'clock in the morning. It fell at night and after sunrise gradually freshened. The following table (No. I) describes the occasions when the wind varied during the 1944 season.

TABLE I.

DATE	Variations from Prevailing Wind.
21st May, 1944.	Wind South - Easterly.
4th - 7th June, 1944.	Little or no wind - Easterly.
23rd, 24th August, 1944.	Southerly winds inthe early morning.
10th September, 1944.	No wind in the morning.
27th September, 1944.	Southerly wind early in morning and at night.
16th October till 3rd November, 1944.	During most of this period the wind was south-easterly or easterly from early morning till early afternoon when it became northerly. After November 3rd winds were variable cold and high.

There was no rain from April 1st till October 13th, when there was a short sharp shower, and then no more till November 6th, when the heavy winter rains started, lasting 3 days. It rained heavily again on 23rd - 24th November. 31.0 mm. of rainfall were recorded in November at a neighbouring meterological unit. In December there was still more rain and 66.3 mm. were recorded.

The following temperature readings from the same Meteorological unit were obtained through the courtesy of the officer in charge.

TABLE II.

MONTH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER
Mean Max. Temperature 1943	67°F	76°F	76°F	88.5°F	83.8°F	83.2°F	83.0°F	76.8°F	62.1°F
Mean Max. Temperature 1944	72°F	75°F	83°F	83.2°F	82.5°F	82.2°F	80.5°F	73.3°F	66.8°F
Mean Min. Temperature 1943	56°F	63°F	69°F	73.7°F	75.7°F	74.3°F	70.3°F	67.2°F	59.9°F
Mean Min. Temperature 1944	60°F	63°F	69°F	74.5°F	74.3°F	72.5°F	67.3°F	61.4°F	55.2°F

Thus, from April to July it was warmer on the whole in 1944 than 1943, but from August on the position was reversed.

The biological situation was closely linked with the level of the lake. The lake is fed by two drains from the fertile country irrigated by canals from the Nile to the East. The lake connects with the sea about 4 miles west of the camp over a sandbar. Mr. R.P. Black, Director General of the Physical Department, Egyptian Ministry of Public Works, was kind enough to send me a chart of the lake level from 1940 - 1944. It is at its lowest in May, starts rising at the end of June and beginning of July with the Nile flood and reaches its peak at the end of August and beginning of September. It then falls till October - November when reinforced by the winter rains, it remains at a constant level till the following spring, when it falls again. The lake is shallow, being about 4 feet at its deepest points and having soft Nile mud as its bed. The difference between the highest and lowest levels is about 15 inches.

In May 1944 when the lake was at its lowest level salinity tests gave a uniform reading of 0.25% at points in the controlled area as much as 5 miles apart. On November 26th 1944, the salinity averaged 0.16%, the drop being attributable to the Nile flood and the November rains. The lake salinity at the outlet to the sea was only 0.02% below the average, showing that the sandbar successfully kept the sea out. That the sandbar did not stop fresh lake water from entering the sea was shown by the salinity of the sea at the outlet. This was 1.6% compared with a reading of 4.6% in the sea some miles away.

Among the fish teeming in the lake are many small larvicides, Gambusia (Bolti - Arabic).

The lake has both vertical vegetation, bulrushes and reeds, and horizontal vegetation, weeds of two types, of which the commonest is potamogeton. The weed grows in two belts parallel to the north lake shore with which we are concerned. One belt is in the shallow water at the lake edge, and the other is in deeper water separated from the first by a belt of reeds. In front of the village the belts of weed amalgamate and form a large expanse of flat surface vegetation about a mile square in area, ending to the last in a mass of reeds and bulrushes. In the midst of the latter there are several pools covered with weed.

In mid-July 1944, the rise of the lake level due to the Nile flood first covered the weed. The fertile Nile water and the higher temperature soon caused the weed to grow very rapidly, and within a month the weed had again reached the surface to form a thick luxuriant brown carpet on the water. It was now noticeable that one or two species of ceratophyllum were growing more rapidly than the potamogeton. As well as being thicker the weed extended over a wider area (it extended at least one kilometer farther west than before).

The rise of the lake in July caused seepages to form or extend east and west of the camp. These were later reinforced by the winter rain. The more shallow seepages were worked as saltpans.

LOCAL MOSQUITOES.

Kirkpatrick (1925) described six Anopheline species found in Egypt, viz:

1. A. pharoensis
2. A. multicolor
3. A. sergenti
4. A. mauritianus (or A. coustani)
5. A. rhodesiensis
6. A. superpictus.

In 1933, A. algeriensis was found at Sitra oasis, and in 1937, A. aegypti and A. turkhudi in the Sinai peninsula (Afifi 1938). Only the first four on Kirkpatrick's list are of practical importance in the Nile delta, and of these, Kirkpatrick considered A. multicolor to be the malaria vector of Egypt while A. pharoensis, he thought, might be a potential carrier.

More recent work by Madwar (1936 and 1938), Barber and Rice (1937), and Afifi (1938) has clearly incriminated A. pharoensis as the important malaria carrier of Egypt, whereas A. multicolor, while it has been infected experimentally, has never been found infected in nature in Egypt, and is not now considered to play any important part in the transmission of malaria in that country. A. coustani has never been infected experimentally or found infected in nature. A. sergenti is strongly suspected on epidemiological grounds of being a vector in certain parts of Egypt. Farid (1940) found a sporozoite rate of 2.7% in this mosquito when investigating a localized malaria epidemic on the eastern edge of the Nile delta, but it was never found in the region with which this thesis is concerned. In this region besides culicines which breed in the lake and seepages and are commonest in August and September, only three Anophelines are found. These are

1. A. COUSTANI.

This species breeds among the bulrushes and reeds at the lake edge. Its breeding commenced in April in 1944. From July till September, it disappeared from our camp. In October it reappeared and increased in numbers till December. It was biting actively well into December, although its numbers fell off. It readily invades buildings and tents, and will attack anyone passing through or near the vegetation in which it breeds.

2. A. MULTICOLOR.

This is the rarest anopheline locally. Breeding appeared first in August in the seepages east and west of the camp formed through the rise in lake level. It was most commonly found in small shallow, muddy, salty pools, found at the edge of the saltpans mentioned above. Animal footprints made ideal nidi. The larvae preferred the muddy bottom to the top of the breeding places. In small numbers this mosquito invades human habitations and as stated above it is not now regarded for practical purposes as a vector. The November rains in 1944 flooded the seepages and stopped breeding.

3. A. PHAROENSIS.

This mosquito is the vector of Egypt. It breeds in great numbers in the weed on the lake (larvae in 1944 was found only once outside the lake in a large seepage which contained weed. They never reappeared there after oiling once). The weed, potamogeton and ceratophyllum, gives shelter from wind, sun and wave motion, and protection from larvididal fish, which cannot penetrate the thickest part of the weed where the mosquito lays its eggs. During the season larvae or eggs were to be found anywhere among the weed along the lake edge, and also during August in the weed round the largest island in the lake.

In 1944 breeding first occurred on the 24th April in the wood opposite the village. It gradually increased and spread from there till, by the beginning of June, breeding was found in the weed opposite the centre of the camp. In July, when the lake level rose, breeding at first diminished. This was due, I believe, to the lake water rising over the top of the weeds. The larvae thus temporarily lost their protection against wind, wave, sun and fish. By August the weed, forced by the rich Nile mud and the warmer weather, had grown to the surface, and was thicker and more widely distributed. A. pharoensis breeding likewise became more prolific and more widespread during August, September and October. The colder weather and rain of November saw breeding drop off. In that month the rain again raised the lake level above the weed tops. No breeding was found after 20th November.

A, pharoensis readily invades tents and messes. It bites at night and also in the morning till about 08.30 hours. In 1944 the adults ceased to be active on the camp after about 20th November, when the winter proper commenced. In a heated mess however, as late as December 5th, the writer saw one of these mosquitoes biting. The next night another was found under an airman's mosquito net in an unheated tent. It had not fed, although it was in the net with two A. coustani which were gorged with blood.

The writer observed that the prevailing north westerly wind blowing from the camp to the lake helped to reduce the number of A. pharoensis adults on the camp. Conversely when the wind was southerly or easterly and blew from the lake or village towards the camp, the catches in the catching stations rose markedly. For example, prior to the southerly winds of 23rd - 25th August, the average daily catch had been about 3 A. pharoensis. On the morning of 26th August, 41 A. pharoensis were caught. Similarly, from 16th October - 5th November, when the morning wind was south-easterly or easterly, the average daily catch, previously 5 adults, rose to anything between 16 to 140 (generally 20 to 40). These mosquito invasions from the malarious village were followed, as will be seen, by a rise in the malaria incidence in the camp.

CONTROL PROBLEM.

At some future date, the Egyptian Government may drain the lake and reclaim the land which it covers. Till then, malaria prevention must be directed to controlling the breeding of Anopheles pharoensis in the weed belts along the northern lake edge.

In 1943, 9 kilometers of lake edge were controlled, 5 kilometers alongside the camp, and 2 kilometers on each side of it. The weed does not grow farther than 2 kilometers west of the camp, but to the east, as described above, the weed belts amalgamate and form a larg e expanse about 1 mile square south of the village. In the season A. pharoensis breeding is prolific here, and malaria is rife in the village.

The writer considered that although the village and its carpet of weed were $3\frac{1}{2}$ kilometers from the eastern edge of the camp, the occasional south-easterly winds were bound to blow mosquitoes at least that distance. This was later proved by the rise in catches, described above, following these winds. Therefore, it was decided to extend the control eastward to include this large breeding area and at the same time to study the effect of doing so on the malaria statistics of the village.

Control had two aspects:-

1. The uprooting of weed.
2. Aircraft spraying of Paris Green.

1. The Uprooting of Weed.

Native gangs were employed for the plucking of weed. They worked in line systematically along the lake edge. In mid-April, 1944, they started uprooting the shallow weedbelt, and by mid-June it was warm enough for them to start work inthe deep belt. At full strength the gangs contained 75 labourers but by the end of August the fishing harvest was at its height and many of the labourers left to help their fellow fishermen in this more lucrative work. The gangs were in this way gradually reduced to half strength.

The growth of the weed became very thick and rapid after the Nile flood. From August to October (inclusive), the labourers, especially since their numbers were depleted, could not keep pace with this increased growth. Cleared areas were again thick with weed after ten to fourteen days. By November 23rd, the water was too cold both for mosquito breeding and for work, and the labourers were therefore discharged.

Weed plucked by the gangs was piled in heaps which were plastered with mud or oil. The A.M.C.U. watched the heaps carefully, as, if they became frayed or broken, mosquito breeding readily occurred round them. Native fishermen had to be prevented from breaking up the heaps and scattering weed over the water to attract fish.

The writer's impression was that this method of control was effective in reducing breeding places from April till August. After this it had little effect. Weed lifting was not extended towards the village. Instead, this extra area was controlled by aircraft spraying alone.

2. Aircraft spraying of Paris Green.

Our area of control was so large and the many channels and cul-de-sacs among the weeds and bulrushes were so difficult of access, that the spraying of a larvicide from the air was the method of choice, if not of necessity. F/O Redmond King introduced this method of control in 1943, using a R.A.F.Lysander aircraft modified for the purpose. In 1944 another Lysander aircraft was made available to us. A different type of dust container (hopper) and control had been fitted. Various modifications were made to this aircraft as a result of our experience and experiments in 1944. In mid-October, it was allotted to another R.A.F. Station and we continued our control with a Royal Egyptian Air Force Avro Tutor (626) which had been modified for spraying by F/Lt. Mitchell of the Air Wing, British Military Mission to Egypt.

Paris Green dust was used for spraying at all times, and it was diluted as required with sand, which had to be imported from a dusty spot in the desert some hours journey away ffom our Station, as local sand was damp and salty, and clogged in the spraying. The Paris Green used was in a dilution of 25% or 33.1/3% by volume in sand.

The Lysander had its dust-tight hopper fitted between the pilot's cockpit and the observer's. The hopper when filled to the brim, held about 760-lbs. of Paris Green and sand mixture. At the bottom of the hopper was a hinged trap which could be closed, or opened at four different apertures. This trap was controlled by a hydraulic system known as an exactor control, operated by a handle in the pilot's cockpit. When the trap was opened, dust fell down a small chute into a venturi tube. This was a sheet metal tube fitted below and in line with the direction of the fuselage. It was constricted at the point or throat, where the dust fell into it, and flared out at both ends, in front being circular, and behind roughly rectangular in cross section. The greater part of it lay behind the throat. The attached photograph (Plate 1) is self explanatory.

PLATE 1.

Venturi.

The forward flight of the aircraft caused high air velocity at the constricted throat, at which point the dust fell into the air stream. The great air turbulence in the rear expanding portion disseminated the dust. This process was assisted by the slip stream. The high velocity of the air stream at the throat also caused some suction which helped to draw in the dust falling from above. Further, the setting of the venturi below the fuselage helped to keep the dust away from the aircraft body and tail.

As the loaded aircraft flew along, when the pilot opened the hopper trap, a cloud of Paris Green and sand mixture was left in its wake. This dust fell to earth, in this case the lake edge, spreading out all the while, and carried by the wind in the direction towards which it was blowing. The attached photograph, though imperfect, (Plate 2) illustrates this. In it the aircraft is seen flying east to west along the northern lake edge, and a northerly wind is carrying the dust south over the weed belts.

PLATE 2.

As the prevailing wind was north-westerly or northerly our routine line of flight was along the northern bank of the lake. This allowed the dust to be satisfactorily distributed over the target area. The aircraft was flown at a height of 30 - 60 feet depending on the strength of the wind. The presence of telegraph poles along the lake edge made flying below 30-feet too hazardous. With a wind of 8 m.p.h. the flight was done at 40 - 50 feet, at 12 m.p.h. 30-feet, and 4 - 5 m.p.h. at 60-feet. The higher the wind the lower the aircraft flew. The spraying was done once every eight to ten days. This interval was found by the A.M.C.U's observations in 1943 to be safe enough to interrupt every breeding cycle throughout the season, though, in the hottest quarter when the breeding cycle was fastest, July to September, we tried to spray weekly. Spraying was done at 08.30 hours during the greatest part of the season. At that time there was nearly always a gentle northerly wind of about 8 m.p.h. and it was not hot enough to make the flight bumpy. As described in Table I, from mid-October till November 3rd the wind did not become northerly till early afternoon. Spraying was always postponed till this happened for the following reasons.

The controlled area contained many pools, channels and cul-de-sacs among the reeds. Experience soon taught the A.M.C.U. which places were likely not to be covered by the dust, owing perhaps to being just in the lee of high bulrushes. These places were always searched after each spraying and hand dusted with Paris Green. Had we sprayed with the wind from another direction we should not have known which spots were not covered, and breeding might have gone on undisturbed there. Spraying was not done if the wind rose higher than 12 - 14 m.p.h. as we found that the dust was simply carried off by the wind, rising in eddies and failing to fall in the control area. Only on one occasion, 30th October, was a spray done with the wind any faster and then the pilot had to fly at such a low height as to be unsafe.

Flying in the morning was always done from east to west along the lake edge so as to avoid flying into the sun, a dangerous procedure when flying low. The aircraft flew at a rate of 90 - 100 m.p.h.

A mosaic aerial photograph of the area to be controlled was taken in May. This proved of the greatest assistance to us as it showed up nooks and crannies among the reeds, where weed was lying, and how best to approach them while searching. It was also essential as a guide for the pilots of the spraying aircraft.

It was calculated from this photograph that at least 900 acres of lake surface required dusting. To allow 1-lb. of Paris Green per acre, the dose advised by more previous workers to give greatest safety (e.g. Williams and Cook, 1927 and 1928, Watson 1936 and Kiker et al 1938) would take 900-lbs. per dusting or 3,600-lbs. per month. Unfortunately, at the time the supply position in Egypt was not good, and our ration at first was only 900-lbs. each month, so that we could only spray ¼-lbs. of Paris Green per acre if we covered the whole area.

A number of experiments to test the effectiveness of this concentration are to be described in the next section of this thesis. In practice we found that this concentration worked quite well, particularly in the open weed area before the village. Areas of lake abounding with larvae were repeatedly found to contain only dead larvae after dusting. In September the R.A.F. Malariologist for Egypt, S/Ldr. O'Leary, was able to have our monthly ration raised from 900-lbs. to 2,000-lbs. per month. As a result we were able to increase our dose of Paris Green to about ½-lb. per acre.

EXPERIMENTS WITH AIRCRAFT SPRAYING.

A. EXPERIMENTS WITH THE LYSANDER.

1. Flow Tests.

On May 13th 1944, F/Lt. Dowding, flying the aircraft at a ground speed of 100 m.p.h., with a full load of 780-lbs., opened the trap at aperture No. 2 (half open). The load endured 3 minutes 3 seconds during which time the aircraft covered 5 miles of the control area. A simple calculation revealed that the rate of flow was about 256-lbs. per minute.

On 17th May, 1944, with F/Lt. Clarkson as pilot, we repeated this test using aperture No. 1 (quarter open). This time a full load endured between 4½ and 5 minutes, and the rate of flow worked out at about 165-lbs. per minute.

With our small ration of Paris Green and with a large area to cover, we had no choice but to use aperture No. 1 in our control.

2. Drift Tests.

On 5th May, 1944, an experiment was done using a load of 130-lbs. of mixture (we used Paris Green one part, to sand 3 parts, by volume). The wind was W.S.W. and about 8 - 10 m.p.h. The pilot, F/Lt. Clarkson, flew across the aerodrome at a height of 50-feet in a line at right angles to the direction of the wind. To the leeward side and at right angles to the line of flight we placed on the ground microscope slides at fixed intervals. The central square inch of each slide was marked by wax pencil, and the top of each slide was slightly greased with vaseline. As the aircraft flew across the aerodrome, the pilot opened the trap at aperture 2 and Paris Green dust escaped and bellowed to the ground, carried by the wind across the ground on which the slides lay. The slides were collected carefully and, under the low power microscope, the number of particles of Paris Green in the central square inch of each was counted. This was best done by setting the reflecting mirror at right angles to the stage when the green particles stand out clearly against a dark background. This test was similar to those done in 1943 by F/O Redmond King. I was assisted in it, as with all the experiments described, by the members of the A.M.C.U. The results are tabulated as follows:-

TABLE III

Result of Drift Test on 5th May, 1944, (Trap at aperture 2).

Distance of slide from aircraft's line of flight.	No. of Particles of Paris Green per square inch of slide.
50-yards	6
100-yards	8
150-yards	25
200-yards	40
250-yards	18
300-yards	12
400-yards	18
500-yards	15

American workers (Williams and Cook 1928 and Watson 1936) showed that 20 to 25 particles (less in some instances) of the Paris Green to the square inch would kill Anopheline larvae. Table III shows that in this experiment these figures were attained only at 150-yards and 200-yards from the line of flight.

Before the test began, unfortunately, some Paris Green mixture was poured into the hopper with the trap open and spilled into the venturi. It was poured back but not before the wind had dissipated some of the Paris Green particles (which were 1/3 to 1/2 as small as the sand particles). The number of particles of Paris Green on the slides would otherwise have been higher than shown.

We did a similar test on 17th May, 1944. F/Lt. Clarkson piloted the Lysander and the trap this time was at aperture No.1. The wind was W.N.W. and about 6 - 8 m.p.h. The aircraft flew at 40-feet. The results are given in the following table:-

TABLE IV

Result of Drift Test on 17th May, 1944 (Trap at Aperture 1).

Distance of slide from aircraft's line of flight.	No. of particles of Paris Green per square inch of slide.
50-yards	32
100-yards	66
150-yards	18
200-yards	30
250-yards	36
300-yards	20
400-yards	13
500-yards	14

This more satisfactory distribution was probably due to the slower speed of the wind and the lack of gusts, and also to the aircraft being flown at a lower height. Also, during this experiment there had been no accidental loss of Paris Green.

3. Biological Tests.

As mentioned in the previous section of this thesis we found in practice that although we were not distributing 1-lb. of Paris Green to the acre over all our controlled area (or 25 particles per square inch) the lower concentration was working quite well especially in the large open area of weed before the village. At the request of Lt.Col. Caplan, an Army malariologist, who visited the station on 8th June 1944, we attempted to test our work with live A. pharoensis larvae. For this purpose the writer devised the following experiments.

On June 13th we placed bowls of water, each containing the same number of larvae, on the aerodrome at right angles to the usual intervals from the aeroplane's planned line of flight. We placed a greased slide beside each bowl. Everything possible went wrong. The wind blew up and scattered the Paris Green dust far and wide, so that on no slide were there more than 10 particles of Paris Green per square inch, and on most less than 5. A dust storm smothered the bowls in sand. The only larvae we had available for the test were late 4th stage. At this stage larvae eat very little. Some even pupated during the test. Because of the advanced stage of the larvae we could not postpone the experiment to a less windy day. 75% of the larvae were dead after 6 hours but no conclusions could be drawn from that.

We repeated the experiment on 11th July, 1944, when there was an 8 m.p.h. wind. Trap aperture No.1 was used which allowed a flow of about 165-lbs. of dust per minute, and we used 25% Paris Green in sand. The pilot flew at 40 feet and at about 100 m.p.h. We placed saucers on the aerodrome at the usual intervals to the lee and at right angles to the line of flight. Lake water was placed in each saucer to a depth of one centimeter and in each saucer we placed ten A. pharoensis larvae of late third or early fourth stage. The number ten was chosen as being the greatest number ever found in the lake in an area the size of a saucer. (As a rule the number found was much smaller). The average diameter of the water surface was 12 cms. The observations were carried out from 09.30 hours to 14.30 hours local time. The saucers were topped up with lake water after one and three hours to counteract evaporation.

A control saucer was kept in the open at station sick quarters away from the Paris Green dust. After the aircraft sprayed the area of the aerodrome where the saucers lay, they were examined at hourly intervals and a count of the dead larvae made. Some larvae lay still and appeared dead but when the water was stirred with a match near them, they could be seen to wriggle. The experiment was stopped after 5 hours as it was obvious how effective the spray had been, and because the control larvae were beginning to die off, due probably to lack of shelter from the sun. The results of the test are given in the following table:-

TABLE V.

Result of Biological Test on 11.7.44.

Saucer Number	No. of larvae in saucer.	Distance from line of air-crafts flight.	Number of dead larvae after				
			1 hour	2 hours	3 hours	4 hours	5 hours.
1.	10	50-yards	9	10	--	--	--
2.	10	100-yards	7	10	--	--	--
3.	10	150-yards	4	10	--	--	--
4.	10	200-yards	0	7	9	9	10
5.	10	250-yards	0	9	10	--	--
6.	10	300-yards	2	6	6	9	9
7.	10	400-yards	1	3	4	6	9
Control	10	Kept at Sick Quarters	0	0	1	2	3

As further control tests were required, this experiment was repeated on 11th August at the same time of day with the same number and stage of larvae, and the saucers at the same points on the aerodrome. As far as possible, all conditions were duplicated except that no spraying was done. Unfortunately, at 13.00 hours the wind speed suddenly rose from 8 m.p.h. to 17 m.p.h. and remained at that speed. As a result the water in the saucers was kept agitated and numbers of larvae drowned. However, considering that in the sprayed test the Paris Green had done the bulk of its work by 13.00 hours, I believe our control was adequate to prove the effectiveness of the spray at the concentration used. The water was again topped up after one and three hours. Larval counts and temperature readings were again done hourly. The results are tabulated in Tables VI (A) and VI (B) below.

TABLE VI (A)

Control Biological Experiment on 11.8.44.

Saucer	No. of larvae in saucer.	Number of dead larvae after 1 hour	2 hours	3 hours	4 hours	5 hours
1	10	0	0	0	2	3
2	10	0	0	1	2	4
3	10	0	0	0	0	3
4	10	0	0	0	0	1
5	10	0	0	0	0	1
6	10	0	0	0	0	5
7	10	0	0	0	0	5
8	10	0	0	1	2	3

Wind increased in strength to 17 m.p.h. at 13.00 hours (see above).

TABLE VI (B)

Temperature readings in degrees Fahrenheit in Control Biological Experiment on 11.8.44.

Time	Air Temperature	Saucer 1	Saucer 2	Saucer 3	Saucer 4	Saucer 5	Saucer 6	Saucer 7	Saucer 8
Commen Cement 09.30 hours.	81	80	80	80	80	80	80	80	80
1 hour after.	81	82	83	81	82	83	82	82	82
2 hours after.	82	83	84	83	83	83	84	83	84
3 hours after.	83	84	85	84	84	84	85	84	85
4 hours after.	83	84	84	85	84	84	84	84	84
5 hours after.	84	85	85	84	85	84	84	84	85

(B) EXPERIMENTS WITH THE AVRO TUTOR (626).

The Avro Tutor was loaned to us by the Royal Egyptian Air Force, and piloted by Egyptian officers. When full its hopper could carry 570-lbs. of Paris Green, but unlike the loaded Lysander, it could not then carry a passenger. It had a trap operated by a handle in the pilot's cockpit and there were 10 possible sizes of aperture for the escape of the dust. It had the usual venturi tube. It sprayed at a speed of about 100 m.p.h.

As we did not operate with the Avro until mid-October, by which time the A.M.C.U. was at skeleton strength, we did not have the personnel needed for elaborate experiments.

We were able to do a number of flow endurance tests, however, and these are tabulated below (Table VII). The conclusion from these was that the rate of flow at a given aperture was not at all constant. As this was possibly due to variations in the density of packing of the dust above the trap, we should have liked to have had installed a simple agitator to see if this corrected the fault. We did not have the opportunity to do this.

TABLE VII

Flow Tests with the Avro Tutor (626)

Date	No. of aperture used.	Rate of flow of dust in pounds per minute.	Remarks
23rd October, 1944	No. 5	180-lbs. per minute.	Across wind.
	No. 4	160-lbs. per minute.	Across wind.
30th October, 1944	No. 5	300-lbs. per minute.	Flying across wind.
	No. 5	440-lbs. per minute.	Flying into wind.
	No. 3	360-lbs. per minute.	Across wind.
	No. 2	270-lbs. per minute.	Across wind.

Experiments with aircraft spraying are laborious with many pitfalls. A number of assistants are required. Sudden changes of weather can ruin a test and controls are difficult to arrange. The judgment of a pilot as to his altitude may be faulty. Winds do not remain constant, and mechanical failures occur. Nevertheless, experimental work is essential for success and must be persevered with.

THE AIRCRAFT SPRAYING IN 1944 - MODIFICATIONS INTRODUCED.

On May 17th, 1944, F/Lt. Clarkson did the first spraying of the year, flying in the Lysander. He distributed one load of 780-lbs. of 25% Paris Green through aperture No.1 over the large weed area opposite the village. So far breeding had been confined to this area.

On May 30th the next dusting was done. The control of the trap was erratic due to partial failure of the exactor control. As a result the flow was uneven. As they had done before during the preliminary tests, the neighbouring R.A.F. unit which serviced the Lysander then adjusted the exactor control, and the next spraying on June 8th was satisfactory. This time the aircraft also sprayed the weed belts alongside the camp where A. pharoensis breeding had now spread. On June 19th this was done again but the pilot flew much too high (80 - 90 feet) and the A.M.C.U. had to do much hand-spraying with Paris Green to compensate. This had also to be done after the next spray on June 29th, when the wind rose too high for successful dusting.

In July, after a satisfactory spray on the 11th, the dust escaped about three times too fast during the spray of the 18th. We therefore repeated the spray on the 20th, but this time the dust escaped too slowly. A repeat spray the following day was successful.

The unit servicing the aircraft, in the hope that they might correct this variable rate of flow, fitted an agitator to the hopper. This was operated by a passenger in the rear cockpit rotating a handle on top of the hopper lid. A shaft led down from this to near the outlet of the hopper, where the small blades of the agitator churned up the dust to prevent it packing.

This modification did not succeed in its object, and it was clear that the exactor control was at fault. I was informed verbally by the R.A.F. Malariologist for Egypt, S/Ldr. O'Leary, that the designer had fitted an exactor control because in theory, it was capable of very fine adjustments so that the pilot could gradually open the trap when a load of dust was becoming exhausted. From this time on till a different design of trap and control was fitted the flow of Paris Green was usually too fast, although the pilots stuck to aperture No.1. On 29th July this occurred, and after a good spray on 5th August, we had it happen again on the 12th.

A serious mishap then occurred. Part of the Lysander's tail assembly became unserviceable and as it is an obsolete machine no spare parts were available, and the required part had to be made in the workshops of our servicing unit. This took a fortnight, during the height of the season, when weekly spraying was essential. The A.M.C.U. did the most extensive handspraying possible in an effort to compensate, but the control suffered.

On 26th August, when the required part was made and fitted, the next spray was done and the flow was again too fast, so that while the aircraft fairly plastered the area it did dust, it could not cover the whole of the ground and the A.M.C.U. had again to do extensive hand spraying. Meanwhile the technical officers of the neighbouring servicing unit were at work designing a new trap and control. At the writer's request they abandoned their plan to fit an electric motor to expel the dust actively and concentrated on a simple mechanical device. This however, was not to be completed and fitted till mid-October.

On 4th September three loads of Paris Green mixture were used of which only the 2nd was distributed satisfactorily. The first and third loads escaped too quickly. On the 12th, the first of two loads escaped too fast but the second was satisfactory. On the 20th September, although the wind was really too high (14 m.p.h.) a spraying was done. As usual, in order to compensate for the very rapid escape of dust, the pilot flew along the course as fast as he could to cover as much of the controlled area as possible. September 29th saw us with our increased ration of Paris Green, and to the pilot's dismay we had four loads of dust for him to distribute, to help compensate for the too rapid flow. We did this again on the 6th of October.

On the 14th October the Lysander operated for the first and last time at our station fitted with the new trap. This consisted of a butterfly type of flap pivotted behind centre across the flap, with a chain operating the final drive.

A cable from the handle in the pilot's cockpit operated the chain. There were five apertures slotted at the handle. This simple trap worked very well and was a big improvement on the exactor control. An even flow of dust was obtained and an excellent spray done. Aperture No.2 gave a flow of 110-lbs. per minute and No.4 aperture a flow of 240-lbs. per minute. Aperture No.3 should have been just right for our control. Unfortunately, we were not given the opportunity to test this as the Lysander was allotted to another station, and we had to carry on with the Avro Tutor.

This machine was based at one hour's flying distance from our station and communications were difficult. It was not possible however, to have the aircraft based locally. As a result we had to arrange for spraying the previous day, and on several occasions when the aircraft arrived, the weather was unsuitable and it had to return to base or wait on our station for the weather to change. This proved inconvenient to the Egyptian Air Force and ourselves.

Another difficulty was that in order to give experience to as many of their personnel as possible, the Royal Egyptian Air Force sent a different pilot for each spraying. This involved for the writer many hours of explanation of the route and technique, to each fresh pilot in turn. Some misunderstandings occurred due to language difficulties. Finally, Moslem festivals, during which no flying could be done by the R.E.A.F., on occasions caused the spraying to be postponed too long or done too soon to be fully effective.

Table VII above summarises our tests with the Avro Tutor. At the trap apertures tested there were considerable variations in the rate of flow of dust.

The following table (VIII) is the most convenient form to describe our experience with the Avro Tutor and the difficulties encountered.

TABLE VIII

Diary of Aircraft Spraying with Avro Tutor.

te of Spray	Pilot	Remarks
th October, 1944	P/O Rizk, R.E.A.F.	Aircraft arrived in evening. Wind next day too strong. Returned to base without spraying.
rd October, 1944	P/O Abdul Hamid, R.E.A.F.	Spraying done in afternoon when wind suitable. First run done too high and too far south. The pilot then got the idea, and did the second and third runs very well. Each load weighed 570-lbs. Today 33% of Paris Green in sand by volume was used. (See table VII for rates of flow of dust at apertures today).
th October, 1944.	P/O Kamil, R.E.A.F.	Lake spray commenced at 13.00 hours when wind became northerly. The wind was actually too fast for spraying (15 - 20 m.p.h.) but the pilot flew so low (20 feet) that a successful spray resulted. This height is however, unsafe because of telegraph poles along the road, and a high building at the village. The runs were done at 100 m.p.h. Apertures No.2 and 3 were used. (See table VII for endurance).
November, 1944.	? ?	Machine arrived to find rain and unfavourable weather and returned to base at once without spraying.
E:- Owing to heavy rain the aerodrome became unserviceable till 13th November, when the station commander passed it as fit for use by light aircraft such as the Avro Tutor. The aircraft did not actually arrive till 16th November, 1944, no less than 17 days after the last spray.		
November, 1944.	F/O Iman, R.E.A.F.	Three loads, each 570-lbs., of 33% Paris Green were sprayed through aperture No.3. The wind was 20 m.p.h. and too fast but owing to the interval since the last spray and the difficulty in getting the machine it was decided to proceed with the spray. The first run was too high, too far south and started too far to the east. During the second run the pilot, misunderstanding his orders, turned south halfway and then circuited the aerodrome spraying it with Paris Green from a height of 500 feet. The third run was satisfactory.
rd November, 1944	? ?	Wind unsuitable. Heavy rain made aerodrome unserviceable until 1.12.44. Aircraft remained on aerodrome.
December, 1944.	F/O Iman, R.E.A.F.	Another Avro Tutor modified for spraying in the same way was used. Three runs were done and aperture No.3 employed. Speed 100 m.p.h. Rate of flow again varied. Satisfactory spray.

In the 1944 season a total of 23 aircraft sprayings were done, 19 with the Lysander and 4 with the Avro Tutor.

MALARIA STATISTICS AT THE CAMP AND VILLAGE.

In 1942 there were 187 cases of fresh malaria notified at our aerodrome. In 1943, after control by aircraft spraying and weed plucking, the figure fell to 55. In 1944, when aircraft spraying was extended to the village as described, the figure again fell to 37, of which 35 were benign tertian and 2 were malignant tertian. (There were also 18 malarial relapses in 1944, 17 B.T. and 1 M.T.)

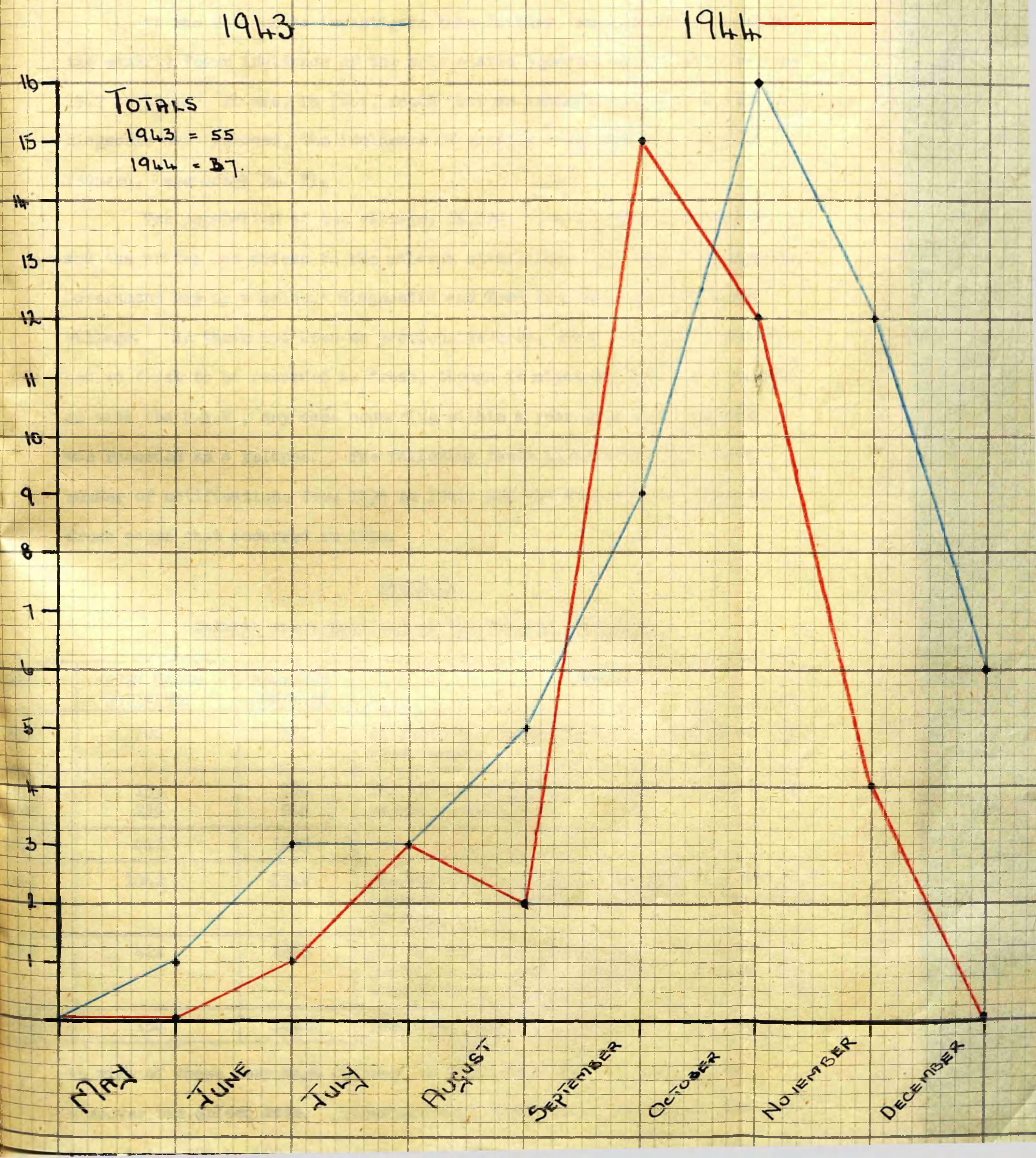
For security reasons the strength of the station cannot be given. It was made up at any one time of a number of squadrons. Of these, all but one were highly mobile, moving in and out at short notice. In 1944, the average station strength throughout the season was a little greater than in 1943, though it was reduced towards the end of the year. The strength in 1942 is not known exactly, but is understood to have been roughly the same as in the two succeeding years. The malaria incidence then was respectively three times and five times greater than in 1943 and 1944.

The attached graph (Graph No.1) gives the monthly case incidence in 1943 and 1944. The month by month incidence of the 187 cases occurring in 1942 is not known. The graph shows that September, October and November were the worst months for malaria on the station. The absence of any cases in December 1944 is probably in part due to the early onset of winter that year. Waves of cases occurred from 14 days after the mosquito invasions at the end of August, and at the end of October and beginning of November. It will be recalled that these invasions were due to south-easterly winds.

Possibly, there was a greater improvement in the malaria position in 1944 than these figures show, for the following reasons. Benign Tertian malaria in Egypt can be mistaken clinically for sandfly fever, as both diseases frequently have the same initial symptoms of pyrexia, frontal headache aggravated by movement of the eyes, and shivering. Mild cases of B.T. malaria may subside without specific treatment. A blood smear or smears will, of course, clinch the diagnosis, but our station was nearly 30 miles by road from the nearest hospital. Prior to 1944 all slides or patients had to be sent this distance for diagnosis, and it would not be surprising if mild cases were now and again treated expectantly, without a smear being taken. In the event of spontaneous recovery, such cases might be labelled sandfly fever. This might also occur if the first

GRAPH No 1

COMPARISON OF R.A.F CASES OF PRIMARY MALARIA INFECTED LOCALLY IN THE YEARS 1943 & 1944.



smears were negative. In 1944, Major Redmond King kindly loaned us a microscope which we held at Station Sick Quarters. We did blood smears on every doubtful pyrexia, and, thanks to the diagnostic skill of my colleague, F/Lt. A.P. Macdonald, R.A.F.V.R., I think this difficulty was avoided in 1944.

It was decided to investigate this further, and the writer studied the sandfly fever incidence of the only static squadron on the station from 1942 to 1944. It was, in fact, found that as antimalarial control and diagnosis had improved, the incidence of sandfly fever had been greatly reduced, (see Graph No. 2).

The population of the village, 26,000, is not a military secret, and the writer had access to the malaria statistics. In 1938, the Egyptian Government set up a malaria diagnostic and free treatment centre in the village. As there had been no previous records, every case that occurred had at first to be recorded as fresh, though it might in fact, be a relapse. As with the R.A.F., any case occurring within a year of a previous attack was recorded as a relapse. The following table illustrates the rising number of notifications from 1938 to 1941, and the drop in the number of fresh cases that occurred in 1944.

TABLE IX

Malaria cases notified at the Village 1938-1944.

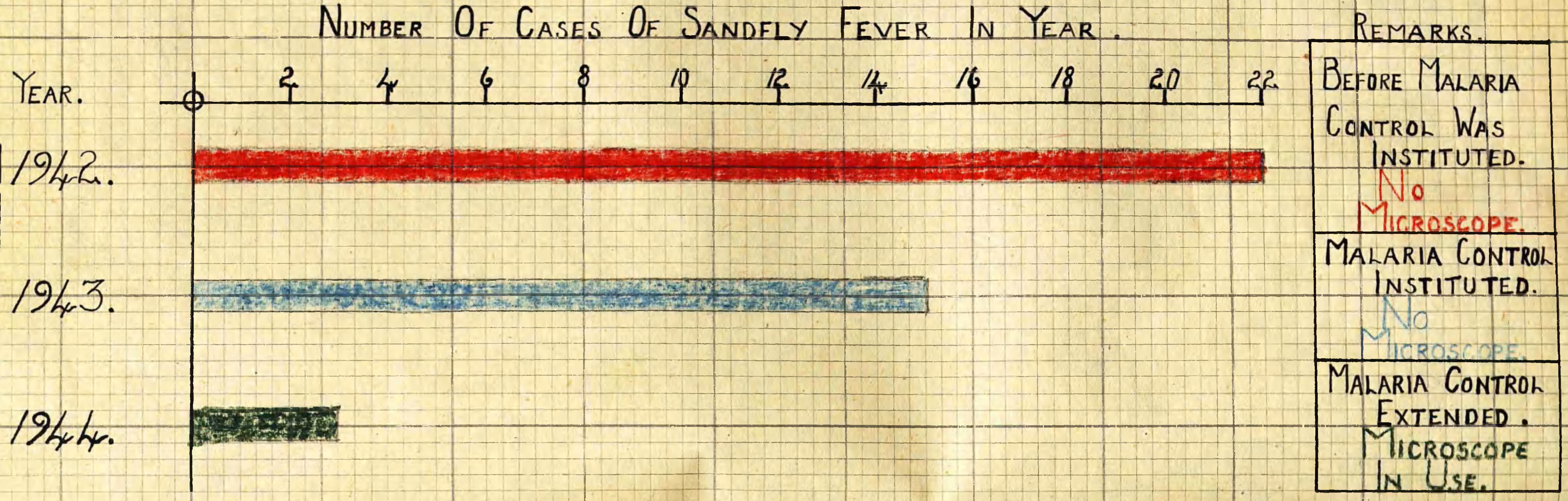
YEAR	FRESH CASES NOTIFIED.	RELAPSES NOTIFIED	REMARKS
1938	706	857	At first all cases had to be notified as fresh. (See above).
1939 1940	155 235	770 915	The Clinic is gradually becoming known to the native community.
1941	446	1637	---
1942	1042	1342	Thousands of non-immune refugees from the Axis bombing of the nearest town swelled the number of fresh cases.
1943	421	1275	All the refugees except for a few hundred returned to the town. Aeroplane spraying and weed lifting commenced opposite the R.A.F. camp.
1944	154	1422	Aeroplane spraying extended to the village.

In view of these very high figures, it would have been of interest to discover the spleen rate. Unfortunately, Bilharzia is also very prevalent, there being 300 to 400 fresh cases yearly according to the local doctor, and so this examination was not done.

With the help of the laboratory worker at the village clinic, I was

Graph No. 2.

Relation Of Sandfly Fever Incidence On "X" Squadron To Malaria Control And Diagnosis In The Years 1942 – 1944.



able to obtain the type incidence of fresh malaria from 1942 to 1944. It is given in the following table:-

TABLE X

Type of fresh malaria occurring at the village from 1942 to 1944.

Year	B.T.	M.T.	Total	Percentage of M.T. in Total
1942	806	236	1042	22.6%
1943	319	102	421	24.1%
1944	136	18	154	11.7%

Thus, in 1944 the incidence of M.T. was relatively half of the incidence in the previous two years.

The following table shows how, at the village, M.T. occurs chiefly in the months of September, October and November. (Of the 2 M.T. cases on the R.A.F. camp, one occurred in August and one in November).

TABLE XI

Monthly incidence and type of fresh malaria at the village for 1942 - 1944.

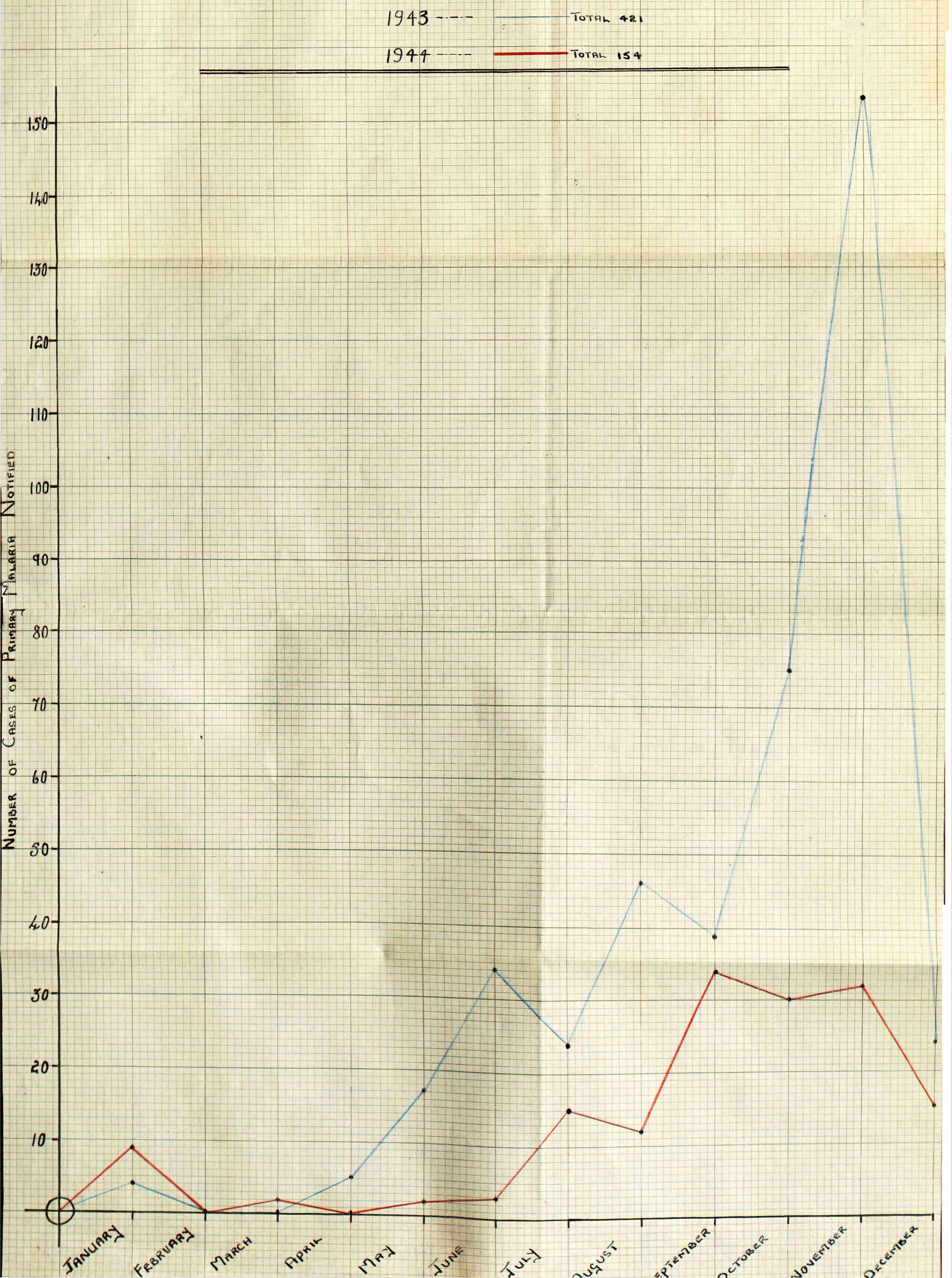
Month	1942			1943			1944		
	B.T.	M.T.	Total	B.T.	M.T.	Total	B.T.	M.T.	Total
January	5	1	6	3	1	4	8	1	9
February	3	4	7	-	-	-	-	-	-
March	7	1	8	-	-	-	1	1	2
April	16	1	17	5	-	5	-	-	-
May	52	1	53	17	-	17	2	-	2
June	56	-	56	34	-	34	3	-	3
July	135	1	136	23	1	24	15	-	15
August	138	3	141	46	-	46	12	-	12
September	240	56	296	37	2	39	34	-	34
October	83	88	171	47	28	75	26	4	30
November	64	67	131	85	68	153	25	7	32
December	7	13	20	22	2	24	10	5	15
TOTALS	806	236	1042	319	102	421	136	18	154

The age incidence of fresh malaria varied. In general most of the cases occurred under the age of 5 years, and the next most numerous group of cases occurred between the ages of 5 and 10 years. There was a sharp fall between the ages of 10 - 15, and anything between one tenth and one third of the total cases occurred over the age of 15. There was no significant difference in the age distribution of B.T. and M.T. malaria.

The improvement in the malaria position at the village following our extended aeroplane spraying is clearly shown in Graph No. 3.

Egyptian Civilian Cases of Primary Malaria Notified at the Village (Pop 26000) in the Years 1943 and 1944

(Malaria Control by R.A.F was Extended to the Village in 1944)



DISCUSSION.

As weed plucking was not done at the village, the only control measure common to both camp and village was aircraft spraying. Prophylactic Mepacrine was not in use in Lower Egypt. Assuming that a control problem arises, for the solution of which aircraft spraying is required, it is necessary to understand the technical requirements. Unless these are fulfilled, results will be disappointing. It is proposed to enumerate and discuss these requirements.

1. The Pilot. Uniformity is necessary. Good spraying is difficult, and requires an experienced pilot. If one pilot does the work throughout the season, he becomes acquainted with the local flying conditions and familiar with the required line of flight. To allow for sickness and leave, another pilot should be given experience with the machine, as is possible in the initial tests.

2. The Aircraft. A variety of aircraft have been used for antilarval spraying. Early American workers (Williams and Cook, 1927 and 1928) used machines such as the T.W.3 and the N.B.2, carrying respectively 200 and 300 pounds of dust. This meant frequent loading which is wasteful. Later workers (including Murray and Knutson, 1944) have used open Stearman biplanes with a 300 h.p. engine, carrying 600 to 800 pounds of dust at a speed of 75 miles per hour, and also Huff Deland open biplanes with 200 h.p. engines, flying at 82 miles per hour, carrying a dust load of 600 pounds. The latter aircraft was actually designed for dusting cotton against the boll weevil. Legendre (1934) used first a Potez 33 with a Salmon 300 h.p. engine and then a Potez 25 with a Lorraine 450 h.p. engine. Covell and Afridi (1937) carried out their trials with a D.H.83 Fox Moth biplane which seems to have worked well.

Our Lysander was powered by an 830 h.p. engine, and the Avro Tutor (626) biplane with an engine of about 270 h.p. The Lysander is much more heavily powered than the other aircraft mentioned, since it was designed for military purposes requiring that power. Its hopper could hold 800-lbs. of dust when quite filled and it could also carry a passenger to operate the agitator when this was installed. The dust load of the Avro Tutor was 570-lbs., and when loaded it could not carry a passenger in addition. All the aircraft mentioned are single engined.

It is essential that a spraying aeroplane should be able to fly low and slow with safety, while carrying an adequate load of larvicide. The Lysander fulfils these requirements, but there were certain objections to it. The pilots agreed that it was unpleasant to fly. The reason is uncertain, but may have been that the venturi blanked off the under-surface of the elevators, making their control difficult. In addition, the Lysander had become obsolete, and spare parts were difficult to obtain. On the other hand, the Avro Tutor, which is a biplane, brought no flying complaints from the pilots, but carried a smaller load of dust and was also obsolete.

The R.A.F. pilots and officers in charge of our servicing suggested that the twin engined Avro Anson would be highly suitable for this work. This type of machine is slow, safe, and easy to fly. Technical experts state that the fitting of a venturi would not affect control. It is manoeverable enough for ~~the~~ work such as we had done. Visibility is very good and spare parts available. Further, an Anson can carry a much larger load and would require few, if any, interruptions of spraying to fill up with Paris Green. On our lake where landmarks were distinctive and it was easy to "pin point" where a spray gave out, this was only a matter of convenience. Elsewhere it might be a necessity.

Points against its use are:

a) It requires a larger landing area than the other types.

b) More man hours must be spent servicing two engines than servicing one.

c) It has a higher stalling speed than, for example, the Lysander, therefore it must fly faster to maintain height and clear obstructions.

d) It is less manoeverable than the Lysander and similar types of machine.

e) The pilot's field of vision is much less than in the Lysander, which is a machine specially designed to give optimum visibility.

The size and nature of the area to be sprayed, whether a wide expanse or narrow and tortuous, and also the aerodrome facilities in its neighbourhood should be considered in deciding the most suitable type of spraying aircraft.

<u>3. The Hopper and Trap.</u> Simplicity must be the keynote. The more complex an apparatus, the more trouble it gives. The exactor control proved a failure from the start, and a simple mechanically controlled trap had to be substituted. In the field in war the servicing of operational aircraft has first priority, therefore spraying apparatus must require very little maintenance.

The hopper should be as dust tight as possible. Paris Green is so light and disperses in the air so readily, that after each spray we found a thin green film over cockpit, pilot and helpers. The dust should be poured into the hopper away from the slightest wind or draught. The pilots did inhale a little dust during each operation, but we saw no ill effects. The quantity inhaled must have been very small.

The hopper itself should be designed with steep shelving sides leading straight down to the trap.

An agitator is necessary to prevent the dust from caking and ensure even delivery to the venturi throat. The simple man-operated type fitted in the Lysander was foolproof. Machines incapable of carrying a passenger must have some form of automatic apparatus, operated, for example, by a small wind propellor fitted on a wing, the action being transmitted through a reduction gear (Watson 1936).

4. The Servicing. There should be every facility for servicing the spraying aircraft near the site of spraying. We were very fortunate in this respect in 1944, and had every possible help and consideration from the neighbouring R.A.F. Station which did this for us.

5. The Paris Green. Metcalf and Hess (1944), in a paper not read till my return to England from Egypt, have shown that by increasing the particle size of Paris Green as far as is compatible with the Anopheline larva's capacity to swallow, a greater proportion of the dust dropped by an aircraft falls in the target area, and a lesser proportion drifts away. They claim a 60% increase in the amount of dust reaching the treatment area by doing this. They state that studies have shown that, in aeroplane dusting in the past, no less than 75% of the Paris Green drifts away from the treatment area due to its fine size.

By the treatment area is meant here the swath covered by the dust cloud dropped from the aircraft. The lower an aircraft flies the narrower relatively is the swath covered by dust. The wind also influences the width of swath. Apart from height and wind, the type of spraying apparatus used and the rate of escape of the dust also play a part in this matter. As the following table shows (XII) different workers have described very different swaths.

TABLE XII.

Author	Height of aircraft and speed of wind (if mentioned)	Width of Swath described
Williams and Cook 1927.	100-feet (Wind 11 m.p.h.)	600-feet
Legendre, 1934	30 - 45 feet	300-feet
Watson, 1936	50-feet	520-feet
Covell and Afridi, 1937	75-feet (Wind 2 to 5 m.p.h.)	360-feet
Watson et al, 1938	20-feet	300 to 600 feet.
Kiker et al, 1938	Not stated	200-feet
Murray and Knutson, 1944	15-feet (wind under 6 m.p.h.)	40-feet clearly defined visibly.

Tables III and IV above showed that in Egypt, with the aircraft flying at 40 to 50 feet and the wind between 6 and 10 m.p.h., we found Paris Green dust over a swath as wide as 500 yards, though only effectively lethal (i.e., having at least 25 particles of Paris Green to the square inch) over a width of 300 to 600 feet. Our experience certainly supports the contention of Metcalf and Hess that much dust does drift away from the effective treatment area. Unfortunately, at the time I did not know of their work and I made no investigation into the particle sizes of the Paris Green we used.

Our original ration of Paris Green was 900-lbs. a month, and as described above, this allowed only $\frac{1}{4}$ lb. of dust per acre for dusting, assuming that none was dispersed outside the treatment area. We found, in practice, that even the low concentration was effective in the wide open weed area before the village. This area was so wide that dispersal of the dust did not matter. However, where weed lay in the lee of high reeds or rushes which blocked the dust, an insufficient quantity of Paris Green penetrated to be effective, and hand dusting had to supplement the aeroplane spraying. Our ration was later increased, as described, but we still kept up the hand dusting of weed areas among thick upright vegetation.

Different powdery substances can be used to dilute Paris Green for spraying. Powdered soapstone (talc) especially, and slaked lime are used in America. We used sand.

Recent research has brought to the fore other highly efficient larvicides, such as D.D.T. Possibly, some such chemical may replace Paris Green in antimalarial control in the future. It would appear that great dilution of D.D.T. may be necessary. If this is so, aircraft would require to carry correspondingly heavy loads consisting largely of diluent.

<u>6. The Technique of Spraying.</u> This will differ in every place. It must be worked out by trial and test on the spot with full knowledge of local geography, wind and weather conditions, and the breeding habits of the local malaria vector. A technique suitable for a wide lake or swamp will obviously not do for a narrow tortuous creek.

<u>7. Aerial Photographs.</u> A good mosaic aerial photograph of the area is, in my opinion, essential in planning a spraying programme. It should be implemented by the officer in charge of the control flying over the area periodically (monthly should be sufficient) to detect changes in vegetation, etc.. It should be noted that a Paris Green spray is better seen from the ground than from the air.

SUMMARY

The malaria problem at an operational aerodrome beside a lake in Egypt is stated, and the bionomics of the mosquito vector described. The chief control measure was the spraying of Paris Green from aircraft over the breeding places of the vector.

In 1944, spraying was extended along the lake edge to the large native village nearby, where the bulk of the breeding occurred. A number of experiments to test the effectiveness of the spraying are recorded, and details given of the spraying experience and difficulties encountered in 1944.

Two modifications to the aircraft, one being the introduction of a hand operated agitator in the dust hopper, the other simplifying the control of the dust outflow were introduced.

The incidence of primary malaria at the aerodrome, reduced following spraying in 1943, fell still further in 1944, and in that year at the village, the incidence fell to about one third of that of the three preceeding years.

The requirements for successful aircraft spraying are discussed in the light of past and present experience.

CONCLUSIONS

1. Aircraft spraying for the control of malaria is practicable under war-time conditions.
2. A modern aeroplane with spare parts available is essential.
3. The aeroplane should be based as near the control area as possible.
4. The spraying apparatus must be simple so that maintenance in the field is easy. An agitator must be fitted in the hopper.
5. Only one pilot, with one in reserve, should fly the aircraft.
6. An adequate reserve of larvicide should be assured.
7. An aerial photograph of the control area is of great assistance in planning the spray.

ACKNOWLEDGEMENTS

My thanks are due to many, in particular to my Commanding Officer, Wing Commander Tom Rowland, for his unfailing support, to Squadron Leader O'Leary, the R.A.F. Malariologist in Egypt, for his advice and help, and to the pilots and technical staff who flew and serviced the aircraft. Corporal D. Jones, the N.C.O. in charge of the A.M.C.U., gave me great help with the experiments and worked unflaggingly throughout the season. Corporals W.R. Gill and C. Foster, L.A.C. G.P. Burton and L.A.C. A. Robinson of my nursing staff gave me their willing assistance with the charts and the clerical side of this work.

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