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Genetical control of *Anopheles gambiae* *

by

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Insecticides are now losing some of their popularity as a means of control of insect pests because of their toxicity hazards vis-à-vis man and his environment (this might be termed the resistance of man to the long-term contamination of his surroundings), and because of the ready ability of the insects themselves to develop resistance. Biological control methods are now being considered and in particular those methods involving the introduction of sterile or incompatible males. The eradication of the screw-worm fly by the large-scale release of insects sterilized by exposure to irradiation has already been achieved over wide areas (BAUMHOVER *et al.*, 1955 ; KNIPLING, 1960). More recently, a preliminary small-scale attempt to eradicate a population of *Culex pipiens fatigans* from a village in Burma by introducing the males of an incompatible strain was completely successful (LAVEN, 1967).

In the *Anopheles gambiae* complex (DAVIDSON *et al.*, 1967), we have the opportunity to make use of the sterile males produced by crossing the member species. This complex consists of at least five sibling species : two salt-water forms from East and West Africa respectively, viz. *A. merus* and *A. melas*, and three fresh-water forms, species A, B and C. Crossing any two of these five species produces what appears to be a normal healthy F_1 generation even showing evidence of hybrid vigour *but* in which the male is sterile. The tests show varying abnormalities in the process of spermatogenesis depending on the parent species involved in the cross.

The addition of these males in varying proportions to cages containing normal males and females has resulted in a significant depression of the number of females subsequently laying fertile eggs. Table 1 summarizes all the laboratory results from these adult additions. The actual species involved were species A and B and hybrid males from crosses between species A and *A. melas*, species B and *A. melas* and species B and *A. merus*. A comparison of expected and actual results shows that under cage conditions, at any rate, hybrid vigour expresses itself as an increased mating ability as well as in other forms such as bigger size and increased longevity.

Certain crosses between member species of the *A. gambiae* complex, in particular those between species A and B males and *A. melas* or *A. merus* females result in an F_1 generation almost entirely composed of males, which again are sterile. This presents a very convenient way therefore of introducing the sterile males in the field — not in the adult stage where a knowledge of when and where to release these males, as well as the necessity of having to rear them to this stage, would be required — but as eggs

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TABLE 1

The effect on the fecundity of the females of adding sterile male adults to cages containing normal males and females.

Actual male proportions		Ovipositions		
Sterile	Normal	Total	% Hatching	Expected %
0	1	308	89	
1/4	1	132	70	71
1/2	1	133	52	59
1	1	339	34	45
2	1	362	23	29
3	1	179	17	22
4	1	133	17	18

into the breeding place with the knowledge that the larvae will grow alongside the normal ones and the adults will emerge with the normal. This has been simulated in the laboratory by adding first-stage larvae from such crosses in known proportions to larval-reasing bowls containing normal first-stage larvae. The mixed larvae have been reared together to the adult stage and these adults left together in cages for a few days. The females have then been fed on blood and tubed individually to see if they laid sterile or fertile eggs. Table 2 summarizes all the results from six series of such larval seeding experiments. The crosses involved were again

TABLE 2

The effect on the fecundity of the females of adding first-stage hybrid larvae (known to produce mostly males which are sterile) to bowls containing normal first-stage larvae and rearing through to the adult stage

Expected male proportions		Ovipositions		Expected %
Sterile	Normal	Total	% Hatching	
0	1	592	85	
1	1	432	48	43
2	1	928	39	28
4	1	206	26	17

between species A and B and *A. melas*, and species B and *A. merus*. The results again show significant changes in the percentage of fertile ovipositions caused by the presence of sterile males, but these changes are not as great as in the adult series of experiments. The reason for this is to be found in the occurrence of varying proportions of hybrid females (which are normal reproductively) in the F_1 generation.

Three of the six series of larval seeding experiments were studied in more detail than the others. The percentages of fertile ovipositions from these three are given in Table 3 from which it can be seen that series II was the most successful. A count of samples of the F_1 generation used in this series showed 16 % of 1,259 individuals were females. In the other two series the percentage was considerably higher — in series III 35 % of 1,817 individuals were female.

TABLE 3

The fecundity results of three series of larval-seeding experiments

Series	Normal strain	Hybrid	Intended proportions of sterile : normal males			
			0 : 1	1 : 1	2 : 1	4 : 1
			Percentages of ovipositions hatching			
I	Pala (A)	Pala (A) ♂ × *melas* ♀	97	81	50	
II	Pala (A)	Kano (B) ♂ × *melas* ♀	87	38	31	19
III	Matemma (B)	Matemma (B) ♂ × *merus* ♀	78	49	43	41

In these three series, when the females were tubed for ovipositions, the males were dissected and classified as sterile or normal from the appearance of their testes. The actual final ratios of sterile to normal males compared with the intended proportions are shown in Table 4. Some of the differences between the actual and expected proportions can be explained by the occurrence of hybrid females in the F_1 generation but where the expected ratio is higher than the intended as enhanced survival of the hybrid male is indicated. This is well illustrated in series II an accounts for the enhanced success

TABLE 4

Intended and actual final proportions of sterile to normal males (as determined by dissection) in the three series of larval-seeding experiments of Table 3

Series	Intended proportion		Actual final proportion	
	Sterile	Normal	Sterile	Normal
I	1	1	0,68	1
	2	1	2,31	1
II	1	1	0,99	1
	2	1	2,66	1
	4	1	4,31	1
III	1	1	0,89	1
	2	1	1,55	1
	4	1	2,69	1

TABLE 5

The effect of adverse rearing on the final ration of sterile to normal males

	Series II 2 : 1 ratio	
	Normal rearing	Adverse rearing
Adult yield	85 %	67 %
Adult survival	74 %	57 %
Final ratio of sterile : normal males	1,81 : 1	3,05 : 1

of this series. In most of the experiments from which the results in Table 4 are derived, yields of adults from first-instar larvae and the subsequent survivals of the emerging adults were high. Attempts to deliberately produce lower yields and lower survivals by poor larval feeding and by breeding in water without vegetation were only partially successful. Most of such experiments, particularly in series II, however, did result in an increase in the proportion of sterile to normal males indicating that the sterile male survives better than the normal under adverse conditions. Actual figures in series II using an intended ratio of two sterile males to one normal are shown in Table 5.

Dissections of males immediately after emergence showed that this increased ratio of sterile to normal males was in part due to differing survivals in the larval stage as is borne out by the figures in Table 6.

TABLE 6

The effect of adverse rearing
on the ratio of sterile to normal males
as determined immediately on emergence

	Series II 2 : ratio
	Adverse rearing
Adult yield	71 %
Ratio of sterile : fertile males	3,47 : 1

As a result of these experiments it is intended to use the hybrid produced by crossing species B males from Kano, Nigeria with *A. melas* females from Harbel, Liberia to attempt to eradicate a population of species A in the village of Pala, near Bobo Dioulasso, Upper Volta in the latter part of 1968. This field trial is primarily designed to find out if the sterile males compete with normal males under natural, as distinct from cage, conditions.

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