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## Review of data on susceptibility of mosquitos in the USSR to imported strains of malaria parasites\*

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*Studies on the susceptibility of mosquitos in the USSR to imported species and strains of human malaria parasites have revealed that Anopheles atroparvus, A. messeae, and A. sacharovi are highly susceptible to strains of Plasmodium vivax from Africa, Asia, and South America. There was no significant variation in the level of adaptation to the various vector species.*

*In experiments on infection of A. atroparvus and A. messeae with imported strains of P. falciparum from Africa and southern Asia, all the results were negative.*

*It was possible to infect A. subalpinus with an African strain of P. falciparum, sporozoites being found in the salivary glands of all the mosquitos studied.*

*Contradictory results have been obtained on the development of tropical strains of P. falciparum in A. sacharovi. In most experiments the parasite did not develop but in 5 experiments, oocysts and sporozoites were seen in 9 mosquitos.*

*Attempts to infect A. atroparvus with West African strains of P. ovale and P. malariae were unsuccessful.*

This paper reviews available data on the susceptibility of mosquitos in the Union of Soviet Socialist Republics to imported strains of malaria parasites from Asia and Africa. In addition to previously published evidence, the paper contains the results of the authors' recent experiments.

Malaria is now being imported to many countries, including the USSR, that were previously free from the infection (1-4), leading to the development of local foci of the disease (3, 5-8). The transmission of the parasite depends primarily on the susceptibility of the local mosquito population to imported plasmodial species and strains, i.e., on the ability of the parasites to develop to the infective sporozoite stage in the mosquito. Studies of the susceptibility of mosquitos to the malaria parasite are therefore an important aspect of public health programmes.

In addition, a comparison of the susceptibility of a

given vector species to various parasite species and strains can be used to study interspecific parasite variability (xenodiagnosis).

Many species of mosquito found in the USSR are specific to the area; therefore, although a large body of data on the susceptibility of foreign mosquitos is available (9-13), the information is not necessarily applicable to transmission of imported strains in this country.

A systematic study of mosquito susceptibility in the USSR to foreign strains of malaria was started in 1975. Before this, the only evidence available had been that described by Tiburskaja (14, 15) who showed that *Anopheles atroparvus* were susceptible to three strains of *Plasmodium vivax* from south-east Asia. To date, four mosquito species have been studied, namely *A. atroparvus*, *A. messeae*, *A. sacharovi*, and *A. subalpinus*. These species are the most effective vectors of local plasmodial strains.

The results of published studies of mosquito susceptibility to imported strains of *P. vivax* (Table 1)

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Table 1. The susceptibility of USSR mosquitos to imported strains of *P. vivax*

Mosquito species	Origin of strain of <i>P. vivax</i>	No. of strains	No. of experiments	No. of gametocytes per $\mu$ l of blood <sup>a</sup>	Autopsy results			
					No. of stomachs examined	No. of salivary glands examined	Oocyst index <sup>b</sup>	Sporozoite index <sup>c</sup>
<i>A. sacharovi</i> (20)	Lao People's Democratic Republic	1	2	144-220 132-325	41	23	29	17
<i>A. messeae</i> (20)	Lao People's Democratic Republic	1	3	70-220 139-325	67	28	34	7
<i>A. atroparvus</i> (20)	Nigeria	1	1	30 51	33	41	12	7
	(20) India	2	2	71- 96 134-170	38	8	13	12
	(20) Pakistan	3	3	17- 44 32- 90	43	40	7	5
	<sup>d</sup> Democratic Yemen	1	13	12-326 35-541	212	275	25	15
	(20) Lao People's Democratic Republic	1	5	63-220 123-325	273	134	24	15
(21) Brazil	1	8	49-555 55-230	98	48	15	14	

<sup>a</sup> Where several experiments were carried out, minimum and maximum values are given.

<sup>b</sup> The percentage of mosquitos with stomach oocysts.

<sup>c</sup> The percentage of mosquitos in which sporozoites were found.

<sup>d</sup> Data not previously published.

Table 2. Susceptibility of various species of the *A. maculipennis* complex to a *P. vivax* strain from the Lao People's Democratic Republic

Mosquito species	Oocyst index (%)	Mean no. of oocysts per infected mosquito	Sporozoite index (%)	Gametocyte survival rate (%)		Oocyst-sporozoite index <sup>a</sup> (%)
				Male	Female	
<i>A. messeae</i>	34 ± 6	6.4	7 ± 5	0.47	0.31	21 ± 7
<i>A. atroparvus</i>	24 ± 3	7.3	15 ± 3	0.49	0.35	62 ± 4
<i>A. sacharovi</i>	29 ± 7	7.2	17 ± 8	0.48	0.39	59 ± 11

<sup>a</sup> 100 × sporozoite index/oocyst index.

have indicated that all the species investigated were susceptible to the parasite. According to published evidence (16-18), *P. vivax* has a wide range of vectors, and there is, therefore, good reason to believe that other species of mosquito capable of transmitting local strains would also be susceptible to imported strains. The wide range of potential *P. vivax* vectors enables it to spread easily to previously non-endemic areas.

When the susceptibility of related *A. maculipennis* mosquitos is compared (Table 2), it can be seen that the development of the parasite to the oocyst stage is similar in all of them but the survival rate to sporozoites is different. The oocyst-sporozoite index (i.e., the percentage of mosquitos with oocysts that then develop sporozoites) in *A. messeae* (21 ± 7%) was

considerably lower than those in *A. atroparvus* (62 ± 4%) and *A. sacharovi* (59 ± 11%) ( $P < 0.01$ ), implying that oocysts develop to sporozoites much less frequently in *A. messeae* than in other species. This may be accounted for either by the destruction of sporozoites or by their failure to reach the salivary glands (17).

The comparison of the development of different strains of *P. vivax* in the same mosquito species and strain revealed only minor differences in the vector's susceptibility. In addition, all the differences found were associated with different levels of starting parasitaemia and with the small size of the sample. There is therefore reason to assume that *P. vivax* is homogeneous with respect to adaptation to vector mosquitos over its entire range. The homogeneity of

Table 3. Results of infection of mosquitos with imported strains of *P. falciparum*

Mosquito species	Origin of strain of <i>P. falciparum</i>	No. of experiments	No. of strains	No. of gametocytes per $\mu$ l of blood		Autopsy results			
						No. of stomachs examined	No. of salivary glands examined	Oocyst index	Sporozoite index
<i>A. subalpinus</i> (22)	Central African Republic	1	1	29	48	0	4		25
<i>A. sacharovi</i> (20)	Upper Volta	2	2	13-14	26-28	35	22	0	0
	Ghana	1	1	30	48	14	7	0	0
	(22) Central African Republic	4	4	29	48	0	20		30
	(21) Central African Republic	2	2	13-27	13-27	17	10	0	0
	(22) Liberia	1	1	3	8	5	0	60	
	(20, 22) Congo	2	2	26	90	15	18	0	0
	(22) Zaïre	1	1	+	+	0	5		0
	(20, 22) Guinea-Bissau	5	5	5-19	5-48	30	31	0	0
	(20) Mali	4	4	8-12	8-25	32	19	0	0
	<sup>a</sup> Guinea	1	1			13	8	0	0
	<sup>a</sup> Equatorial Guinea	1	1	17	51	9	4	0	0
<sup>a</sup> India	1	1			10	8	0	0	
<sup>a</sup> Pakistan	1	1			11	11	0	0	
<i>A. atroparvus</i> (20)	Mali	8	7	7-12	8-25	214	246	0	0
	(20) Guinea-Bissau	5	5	6-60	5-48	172	129	0	0
	(20) Guinea	1	1			38	29	0	0
	(20) Ivory Coast	1	1	48	36	33	22	0	0
	(20) Upper Volta	2	2	13-40	26-28	86	60	0	0
	(20) Ghana	1	1	30	46	51	31	0	0
	(20) Central African Republic	2	2	13-27	13-27	50	46	0	0
	<sup>a</sup> Togo	1	1	24	12	37	24	0	0
	(20) Somalia	2	2	38-71	50-114	65	38	0	0
	(20) Zambia	1	1	11	11	33	35	0	0
	<sup>a</sup> Equatorial Guinea	5	5	17-62	33-132	107	114	0	0
	(20) Congo	2	2	10-26	20-90	75	46	0	0
	<sup>a</sup> India	2	2	12	22	45	44	0	0
	<sup>a</sup> Pakistan	1	1			49	31	0	0
<i>A. messeae</i> (20)	Mali	4	4	8-12	8-25	63	58	0	0
	(20) Guinea-Bissau	3	3	6-12	5-18	62	53	0	0
	<sup>a</sup> Guinea	1	1			27	21	0	0
	(20) Upper Volta	2	2	13-14	26-28	39	38	0	0
	(20) Ghana	1	1	30	46	19	18	0	0
	(20) Central African Republic	2	2	13-27	13-27	29	19	0	0
	<sup>a</sup> Equatorial Guinea	1	1	17	51	10	7	0	0
	(20) Congo	1	1	26	90	26	7	0	0
	<sup>a</sup> India	1	1			22	16	0	0
	<sup>a</sup> Pakistan	1	1			18	16	0	0

<sup>a</sup> Data not previously published.

Table 4. Results of infection of *A. atroparvus* with imported strains of *P. ovale* and *P. malariae*

Parasite	Origin of plasmodial strain	No. of strains	No. of experiments	No. of gametocytes per $\mu$ l of blood		Autopsy results			
						No. of stomachs examined	No. of salivary glands examined	Oocyst index	Sporozoite index
<i>P. malariae</i>	Guinea	1	1	25	33	10	21	0	0
<i>P. ovale</i>	Guinea	2	2	9-14	14-18	41	50	0	0
	Mali	1	1	9	13	27	24	0	0
	United Republic of Tanzania	1	1	30	40	31	32	0	0
	Mozambique	1	1	20	30	29	16	0	0
	Central African Republic	1	1	12	24	68	27	0	0

*P. vivax* explains the potential danger associated with the importation of any strain from any part of this species' range.

The results of several studies of mosquito susceptibility to imported strains of *P. falciparum* are shown in Table 3. *A. atroparvus* and *A. messeae* were not susceptible to strains of *P. falciparum* from Africa and south-east Asia. The data obtained are in agreement with previously published evidence (10, 11).

Experiments to determine the susceptibility of *A. sacharovi* to imported *P. falciparum* strains have produced contradictory results. In most cases (21 experiments on 300 mosquitos) parasite development was not seen, but a few experiments did yield positive results. More work is needed before any firm conclusions can be drawn on this subject.

In an experiment on infection of *A. subalpinus* with an African strain of *P. falciparum*, sporozoites were found in the salivary glands of the mosquito.

The development of *P. falciparum* in *A. sacharovi* and *A. subalpinus* suggests that other southern species may also be susceptible to tropical strains of

the parasite. More studies are needed to test this assumption.

Our experiments have revealed differences in the level of adaptation to the vector of various *P. falciparum* strains. *A. atroparvus*, *A. messeae*, and *A. sacharovi* are effective vectors of the local strains of the parasite, but in relation to the imported strains the former two proved unsusceptible, while the latter was possibly susceptible in some cases. Similar results have also been obtained by researchers in other countries (9, 10), indicating that *P. falciparum* is heterogeneous over its range (19).

A study of mosquito susceptibility to imported strains of *P. ovale* and *P. malariae* was carried out on a small sample since these parasite species are imported to the USSR comparatively rarely. In all the experiments (Table 4) no development of the parasite in *A. atroparvus* was recorded. In relation to *P. ovale* the results obtained suggested a low level of adaptation, if any, of the parasite to the mosquito species under study.

## RÉSUMÉ

### EXAMEN DES DONNÉES RELATIVES À LA SENSIBILITÉ DES MOUSTIQUES D'URSS À DES SOUCHES IMPORTÉES DE PLASMODIES

Des études portant sur la sensibilité des moustiques d'URSS à des espèces et à des souches importées de plasmodies humaines ont révélé qu'*Anopheles atroparvus*, *A. messeae* et *A. sacharovi* présentaient une très grande sensibilité aux souches de *Plasmodium vivax* d'origine africaine, d'origine asiatique et d'origine sud-américaine. Le degré

d'adaptation aux diverses souches ne variait pas de façon considérable.

Toutes les tentatives d'infection expérimentale d'*A. atroparvus* et d'*A. messeae* à l'aide de souches importées de *P. falciparum* provenant d'Afrique et d'Asie méridionale ont échoué. On a pu infecter *A. subalpinus* au moyen d'une

souche africaine de *P. falciparum*, la confirmation étant obtenue par la présence de sporozoïtes dans les glandes salivaires de tous les sujets étudiés.

Les essais en vue de faire se développer des souches tropicales de *P. falciparum* dans l'organisme de *A. sacharovi* ont donné des résultats contradictoires. Dans la plupart des ex-

périences, le parasite n'a pas pu se développer, mais dans 5 d'entre elles, en revanche, on a observé chez 9 moustiques la présence d'oocystes et de sporozoïtes.

Les tentatives en vue d'infecter *A. atroparvus* au moyen de souches ouest-africaines de *P. ovale* et de *P. malariae* ont échoué.

## REFERENCES

1. SERGIEV, P. G. ET AL. [Malaria in USSR in 1963-1965 and trends in prevention for 1966-1970.] *Medicinskaja parazitologija i parazitarnye bolezni*, **35**: 444-457 (1966) (in Russian).
2. NEMIROVSKAJA, A. I. ET AL. [Concerning analysis of imported malaria.] *Medicinskaja parazitologija i parazitarnye bolezni*, **38**: 200-206 (1969) (in Russian).
3. ČAGIN, K. P. ET AL. [The problem of importation of malaria to the USSR.] *Medicinskaja parazitologija i parazitarnye bolezni*, **44**: 396-405 (1975) (in Russian).
4. DAŠKOVA, N. G. ET AL. [Importation of malaria to Moscow from abroad.] *Medicinskaja parazitologija i parazitarnye bolezni*, **47**: 105-109 (1978) (in Russian).
5. AMBROISE-THOMAS, P. ET AL. Reappearance of malaria in Corsica. Importance of a sero-epidemiological survey. *Bulletin de la Société de Pathologie exotique et de ses filiales*, **65**: 533-542 (1972).
6. DE ZULUETA, J. Malaria eradication in Europe: the achievements and the difficulties ahead. *Journal of tropical medicine and hygiene*, **76**: 279-282 (1973).
7. SCHULTZ, M. G. Imported malaria. *Bulletin of the World Health Organization*, **50**: 329-336 (1974).
8. ČAGIN, K. P. ET AL. [Importation of malaria to the USSR and prevention of its epidemiological consequences.] In: *Aktualnij problemy etiologii, patogeneza, kliniki i lečenija tropičeskij boleznei*. Moscow, 1976, pp. 19-21 (in Russian).
9. GAMES, F. Some general results of a study of induced malaria in England. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **24**: 478-534 (1931).
10. SHUTE, P. G. & MARYON, M. Studies in the transmission of *P. malariae* by *Anopheles* mosquitoes. *Parasitology*, **41**: 292-300 (1951).
11. DE ZULUETA, J. ET AL. Receptivity to malaria in Europe. *Bulletin of the World Health Organization*, **52**: 109-111 (1976).
12. COLLINS, W. E. ET AL. Studies on human malaria in *Aotus* monkeys. I. Sporozoite transmission of *P. vivax* from El Salvador. *Journal of parasitology*, **59**: 606-608 (1973).
13. COLLINS, W. E. ET AL. Studies on human malaria in *Aotus* monkeys. 6. Infectivity of *Plasmodium malariae* to different anophelines. *Journal of parasitology*, **61**: 941-943 (1975).
14. TIBURSKAJA, N. A. [On duration of the incubation period of the malaria induced by a Korean strain of *P. vivax*.] *Medicinskaja parazitologija i parazitarnye bolezni*, **31**: 643-648 (1962) (in Russian).
15. TIBURSKAJA, N. A. [A description of the strains of the tertian fever parasite inducing the manifestation of infection after brief incubation.] *Medicinskaja parazitologija i parazitarnye bolezni*, **34**: 667-672 (1965) (in Russian).
16. BOYD, M. F. & KITCHEN, S. F. The comparative susceptibility of *Anopheles quadrimaculatus*, Say, and *Anopheles punctipennis*, Say to *Plasmodium vivax*, Grassi and Feletti and *Plasmodium falciparum* Welch. *American journal of tropical medicine*, **16**: 67-73 (1936).
17. COLLINS, W. E. ET AL. Development of different strains of *Plasmodium vivax* in two species of *Anopheles*. *American journal of tropical medicine and hygiene*, **25**: 373-375 (1976).
18. COLLINS, W. E. ET AL. Studies of human malaria in *Aotus* monkeys. 7. Comparative infectivity of two strains of *P. vivax* to *An. freeborni*, *An. maculatus* and four strains of *An. albimanus*. *Journal of parasitology*, **62**: 490-494 (1976).
19. LYSENKO, A. Ja., & BAROJAN, O. V. [Malaria.] In: Barojan, O. V. & BRADELY, J., ed., [A new view of tropical pathology], Moscow, Medicina, 1979 (in Russian).
20. DAŠKOVA, N. G. Zarazyvanie na *An. m. atroparvus* s vneseni Schamove na tridnevna malaria i tyahnoto epidemiologično značenie. *Letopisi na higijeno-epidemiologičnata služba*, **4**: 160-164 (1977).
21. BIBIKOVA, V. A. ET AL. [Experimental study of susceptibility of mosquitos to imported strains of human malaria parasite.] In: *Tezisy dokl. XVI Vsesojuznogo syezda mikrobiol. i epidemiol.* Ulianovsk, 1977, p. 259-261.
22. DZAVADOV, R. B. ET AL. [On susceptibility of the mosquitos *Anopheles m. sacharovi* and *Anopheles m. subalpinus* to infection with tropical malaria parasites from Africa.] *Medicinskaja parazitologija i parazitarnye bolezni*, **47**: 84-87 (1978) (in Russian).