TROPICAL EXTENSION OF TEMPERATE ZONE *CULEX PIPIENS* THROUGHOUT EGYPT

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ABSTRACT. To explore the southern limit of the temperate zone form of the *Culex pipiens* complex of mosquitoes in North Africa, we compared the structure of the copulatory structures of such male mosquitoes sampled along the length of Egypt. Larval mosquitoes were collected in 11 sites distributed along the entire Egyptian span of the Nile Valley as well as in sites along the central Red Sea coast and in the western desert. Four of these sites were sampled repeatedly, at various times of the year. A DV/D ratio was calculated for each adult male mosquito. Although all DV/D values conformed to criteria normally attributed to the temperate zone form, even at the southernmost site (22°N), values tended toward those of the tropical form in southern sites and during the summer months. We concluded that *Cx. pipiens* mosquitoes of the Middle East are predominantly Mediterranean in form due to an isolating effect of the Sahara Desert which separates these temperate zone insects from those of tropical Africa.

INTRODUCTION

The *Culex pipiens* complex of mosquitoes comprises a cosmopolitan array of insects geographically differentiated into 2 main morphologically distinct subspecific groupings mainly according to the shape of the aedeagus. Temperate-zone *Cx. p. pipiens* Linn. populations have been distinguished from the more tropical *Cx. p. quinquefasciatus* Say mainly on the basis of the angle formed by the ventral (designated V) and dorsal (D) arms of the aedeagus (Sundararaman 1949). These anatomical conventions, unfortunately, are dorso-ventrally reversed (Spielman 1966). The resulting DV/D ratio describes a parapatric relationship that closely follows the northern 33rd meridian in North America and Asia and occurs in scattered sites in the southern hemisphere (Mattingly 1951). Mosquitoes with DV/D ratios intermediate between *pipiens* and *quinquefasciatus* have been reported wherever the forms coexist (Barr 1967). In general, transmission of lymphatic filariasis has been associated with the presence of the *quinquefasciatus* form.

The distribution of these mosquitoes in the Middle East, however, does not conform to the pattern that exists in other parts of the world (Nudelman et al. 1988). In Israel, the range of the northern *pipiens* form extends south at least to the 30th meridian. Toward the east, however, the *quinquefasciatus* form has been recorded at a northern latitude in Iraq (Knight 1951) that is consistent with its 33°N distribution. This southern form has been collected in Yemen (Knight 1953), Dubai in the United Arab Emirates (Holmes 1986) and in Sudan at a northernmost latitude of 15°N (El Rayah and Abu Groun 1983). Various local collections of these mosquitoes from Egypt suggest that only the *pipiens* form may occur there, perhaps extending to the southern border of that country at 22°N (Edwards 1921, Kirkpatrick 1925, Harbach et al. 1984, Knight and Abdel Malek 1951, Khalil 1981, Gad et al. 1987). Because lymphatic filariasis is endemic to Egypt, the precise identity of the vector should clearly be established.

Accordingly, we conducted a comprehensive geographical survey of the *Cx. pipiens* mosquitoes of Egypt in order to determine the southern limits of the distribution of the *pipiens* mosquitoes of the Middle East. We particularly sought to determine whether seasonal variation may affect the distribution of the forms, as described by McMillan (1958) and Jakob et al. (1980).

MATERIALS AND METHODS

Larval and pupal *Cx. pipiens* mosquitoes were collected throughout a 1-year period along the entire length of Egypt, from 22 to 31°N latitude (Fig. 1). In the Nile Delta, Beheira, Sharqiya and Qalubiya Governates were surveyed. Giza Governate was surveyed along the central Nile region. We surveyed Faiyum Oasis in the western desert and the Red Sea Governate toward the east. The southern Aswan Governate was surveyed south to the Sudan border. Mosquitoes were collected mainly from cesspits, but also from cesspools, polluted seepage water and drainage canals. Each site was surveyed repeatedly throughout the year, or when water was present.

Field derived larval and pupal mosquitoes were held at 27 ± 2°C in water derived from the original site and fed Tetramin fish food. Derived adults were maintained for 3–4 days and fed 5% sucrose. Males were then killed by freezing and stored in 70% alcohol. Genitalia of males were mounted on slides in rows as described by Sun-

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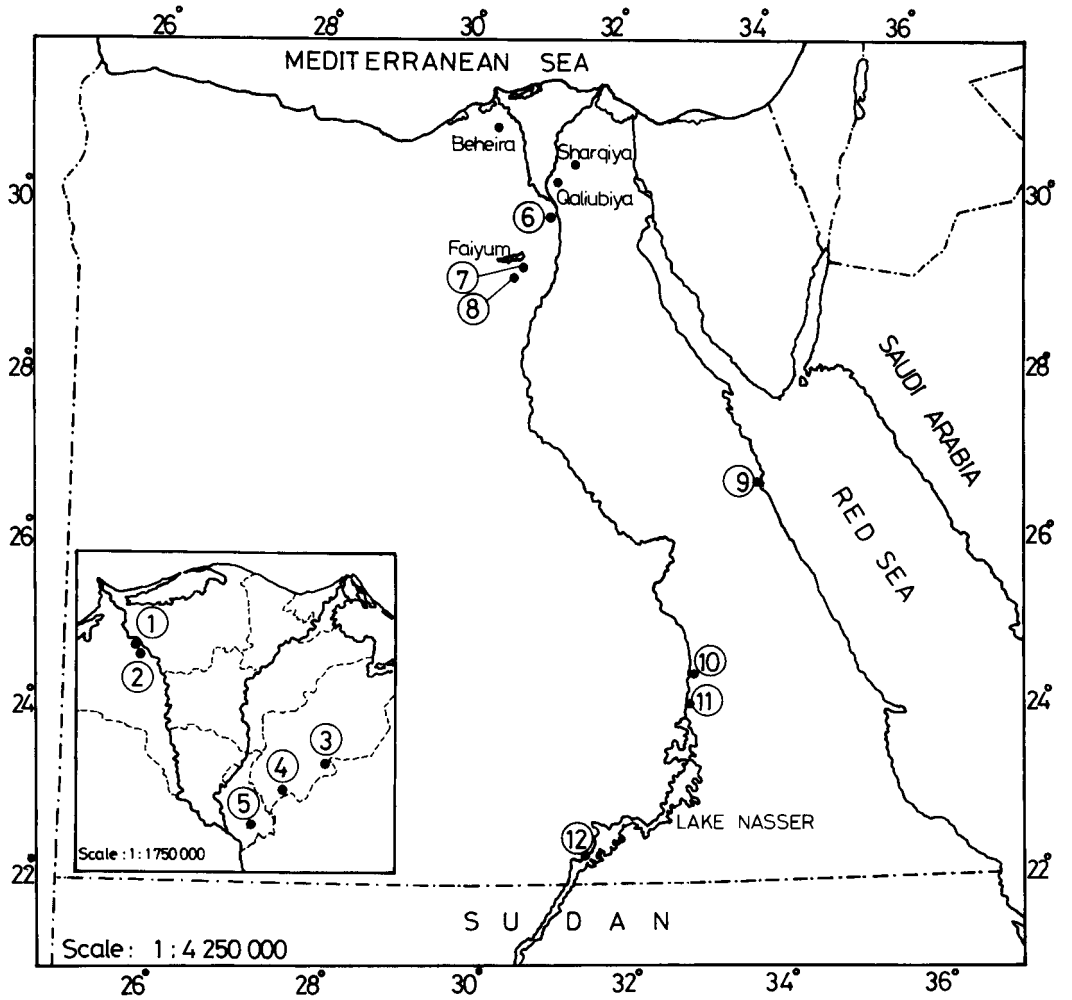

Fig. 1. Map of Egypt showing the mosquito collection localities. 1. Karakes; 2. Rahmaniya; 3. Abbassa; 4. Abu Hif; 5. El Kashish; 6. El Sheikh Etman; 7. Agamyin; 8. El Nazlah; 9. Safaga; 10. Kom Ombo; 11. Aswan; 12. Abu Simbel.

dararaman (1949). Distorted specimens were discarded.

Genitalia were examined using 100× magnifications. The parameter D was derived by measuring the distance between the external tips of the conventionally designated dorsal arms using an ocular micrometer. DV was derived as the average of the distances between each pair of these arms and the corresponding conventionally designated ventral arms.

RESULTS

The genitalia of 1,241 male mosquitoes were examined. The dorsal arms of the aedeagus invariably were broad, truncate apically and divergent. The ventral arms were slender, wing-like and contained within the margins of the dorsal arms. The DV/D ratio invariably was assigned a negative value and occasionally approached 0 (Table 1). Thus, the structure of the aedeagus of all collected mosquitoes conformed to values conventionally assigned to *pipiens* mosquitoes.

To determine whether the genitalia of these mosquitoes may have varied in some pattern over the study region, the DV/D ratios of mosquitoes derived from different sites were compared. A one-way analysis of variance suggested a significant ($P = 0.01$), but slight trend toward 0 values in the southernmost collections between Kom Ombo and Abu Simbel (Table 1).

We compared the DV/D ratios of mosquitoes derived from different kinds of breeding sites.

Table 1. Variation in the DV/D ratios of male *Culex pipiens* mosquitoes sampled along the length of the Egyptian segment of the Nile River and in sites in a western oasis and on the Red Sea coast.

Latitude			No.	DV/D ratio		
°N	′	Locality	males	Mean	±SD	Range
31	01	Karakes	335	0.11	0.03	0.02–0.20
	05	Rahmaniya	119	0.10	0.03	0.00–0.18
30	31	Abbassa	45	0.11	0.04	0.05–0.16
	20	Abu Hif	154	0.11	0.04	0.00–0.21
	14	El Kashish	4	0.09	0.01	0.07–0.10
29	53	El Sheikh Etman	77	0.13	0.03	0.08–0.18
	20	Agamyin	32	0.11	0.03	0.03–0.16
	18	El Nazlah	32	0.09	0.03	0.00–0.14
26	44	Safaga	38	0.10	0.03	0.04–0.15
24	28	Kom Ombo	115	0.13	0.03	0.03–0.21
	05	Aswan	268	0.09	0.03	0.00–0.21
22	19	Abu Simbel	82	0.10	0.04	0.00–0.31

Thus, enclosed cesspit sites were compared to open seepage waters and to drainage canals (data not displayed). The DV/D values were similar, regardless of the nature of the site in which the larvae were collected.

The effect of season of collection on the structure of the aedeagus was then compared. The DV/D ratios of northern Sharqiya mosquitoes seemed to diverge from 0 more in winter than in summer, and those from the southern Aswan site diverged more in summer (Table 2). The ratios of Beheira mosquitoes appeared relatively constant throughout the year. These marginal and contrasting seasonal trends in DV/D values seem ambiguous.

Table 2. Seasonal variation in the DV/D ratios of male *Culex pipiens* mosquitoes sampled at various latitudes in Egypt (31°N in Beheira, 30° in Sharqiya, 29° in Faiyum and 24° in Aswan Governates).

°N		No.	DV/D ratio	
Latitude	Season	males	Mean	±SD
31	Winter	201	0.10	0.03
	Spring	125	0.11	0.03
	Summer	16	0.10	0.04
	Fall	112	0.11	0.03
30	Winter	36	0.12	0.03
	Spring	54	0.12	0.04
	Summer	63	0.11	0.04
	Fall	46	0.08	0.03
29	Winter	0	—	—
	Spring	32	0.09	0.03
	Summer	0	—	—
	Fall	32	0.11	0.03
24	Winter	214	0.09	0.03
	Spring	0	—	—
	Summer	251	0.12	0.04
	Fall	0	—	—

DISCUSSION

Our finding that the north-temperate characteristics of the *Cx. pipiens* complex of mosquitoes predominate deep into the Sahara desert is consistent with their pattern of distribution along the course of the Nile River. These highly domestic mosquitoes densely infest the continuously populated stretch of the Nile and Mediterranean coast that lies north of the Sudan border. The Sudanese Nile, however, is sparsely and discontinuously populated. This land barrier appears to inhibit migration of tropical mosquitoes north toward the Mediterranean coast. The pattern of human settlement and commerce along the Nile River provides opportunity for these exclusively domestic mosquitoes to disseminate south from the cities of Europe and Asia. These zoogeographical considerations reflect the effect of human activity on the distribution of associated organisms.

The presence of forms intermediate in appearance between the temperate and tropical forms of the complex suggest that these organisms may hybridize as freely in nature as in the laboratory (Rozeboom and Gilford 1954). Although such mosquitoes appear not to occur where the *pipiens* and *quinquefasciatus* forms are contiguous in South Africa (Donaldson 1979, Muspratt 1955) and Australia (Miles 1977), they have frequently been recorded across the United States of America (Barr 1967, Tabachnick and Powell 1983) and in Japan (Ishii 1980). Our finding that the DV/D ratios tend to be less skewed toward the *pipiens* extreme in southern than in northern Egypt reflects the reported presence of intermediate forms in other distant parts of the world (Mattingly 1951). Although these mosquitoes fulfill the taxonomic criteria for *Cx. p. pipiens*, we suggest that their structure reflects importation of mosquitoes from more southerly regions.

The somewhat *pipiens*-like DV/D values that

we observed during the summer months in the Aswan region reflect those reported for North America (McMillan 1958) and stand in contrast to those observed in northern Egypt. Diapause relationships could explain a fall-season shift in DV/D values from the hibernating *pipiens* to the nonhibernating *quinquefasciatus* forms because such hibernating mosquitoes cease to reproduce in late summer, at least at 42°N latitude (Spielman and Wong 1973).

Egyptian *Cx. pipiens* appear to form a relatively panmictic array of populations. Their integrity appears to be maintained mainly through geographic isolation due to the Mediterranean Sea and the extensive deserts that isolate this region from neighboring points of infestation.

ACKNOWLEDGMENTS

This work was supported in part by the Regional Project, Epidemiology and Control of Arthropod-Borne Diseases in Egypt—NO1 AI 22667 between Ain Shams Research and Training Center on Vectors of Diseases, Ain Shams University, Abbassia, Cairo, Egypt, and the National Institute of Allergy and Infectious Diseases, National Institutes of Health, Bethesda, MD.

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