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The life cycle of the tick *Hyalomma anatolicum excavatum* Koch, 1844, maintained under field conditions in Israël

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RÉSUMÉ

La biologie d'*Hyalomma anatolicum excavatum* Koch, 1844, dans les conditions naturelles en Israël

La biologie d'*Hyalomma anatolicum excavatum (H.a.e.)* a été étudiée sous conditions naturelles en Israël. La durée des périodes de pré-oviposition, éclosion, mue larvaire et nymphale ainsi que la survie des jeunes larves, nymphes et adultes ont été déterminées.

Les tiques exposées au cours des mois d'octobre-mars (« tiques d'hiver ») ont eu une évolution prolongée due principalement à une inhibition de la ponte chez les femelles gorgées et aux mues retardées des larves et des nymphes. La durée de la période d'éclosion a été, elle aussi, plus longue que celle trouvée chez les tiques exposées pendant l'époque d'avril-septembre (« tiques d'été »).

Le pourcentage des femelles gorgées qui ont pondu a été beaucoup plus bas chez les tiques d'hiver que chez celles d'été. De la même manière, le taux des larves et nymphes qui ont mué a été plus bas et la longévité des jeunes larves, nymphes et adultes plus courte chez les tiques d'hiver.

Il semble que les processus biologiques étudiés plus haut sont réglés par l'effet combiné du photopériodisme et de la température. Il en résulte que les stades pré-imaginaux sont rares ou même absents pendant la difficile période de l'hiver, alors que les adultes se trouvent actifs principalement en été. Dans les conditions naturelles, le déroulement d'une génération de H.a.e. demande, en Israël, 1-2 ans. Les données rapportées dans cette étude doivent être prises en considération lors de la préparation de campagnes anti-tiques.

INTRODUCTION

Hyalomma anatolicum excavatum (H.a.e.) has been shown to be widespread on cattle in Israel (13, 18) and might be involved in the transmission of theileriosis caused by *Theileria annulata* (8, 17, 23). This tick species has been found on livestock throughout the year, almost exclusively in it's adult stage (13, 18) while larvae and nymphs have been recorded from hares and small rodents (25, 26).

The biology of *H.a.e.* has been studied under laboratory conditions by various authors (9, 10, 11, 12, 14, 21, 24). Few studies are available on this species development under field and outdoor conditions (7, 11). In the present work, the life cycle of *H.a.e.* collected from cattle in Israel has been studied under natural conditions.

MATERIALS AND METHODS

The observations described were carried out during the period of January, 1975-December, 1977, in the vicinity of the Kimron Veterinary

Institute, Beit-Dagan, 12 km south-east of Tel-Aviv.

The site is located in the mediterranean phyto-geographical zone characterized by an average winter rainfall of 500-600 mm followed by a long rainless and hot summer.

Ticks and tick exposure

About 22 000 ticks of various developmental stages were used in the study (Table I). The ticks were bred on jirds *(Meriones tristrami)* as described by HADANI *et al.* (14). Batches of *H.a.e.* engorged larvae, nymphs and females were exposed monthly in a heavily grassed plot partly shaded by cypress trees *(Cupressus sempervirens)*. The exposure method used was that of HARLEY (19) slightly modified. A single engorged female tick or up to 100 engorged larvae were placed in small plastic tubes, 4 cm long and 2 cm in diameter, sealed on each side with a nylon stocking. The tubes were placed in plastic cylinders, 25 cm high and 25 cm in diameter and were tightly embedded in the soil so that the ticks were lying 1-2 cm below the ground level.

Hundred engorged nymphs were placed freely in each cylinder, the free margin of which was smeared with tanglefoot to prevent escape (15). The nymphs generally buried themselves in the litter where they could easily be examined. For comparison in the laboratory similar batches of ticks were placed in glass tubes in an incubator at 29 ± 1 °C and 75-80 p. 100 relative humidity (RH), illuminated continuously with fluorescent light. Ticks exposed during the fall-winter months of October-March were designated as « winter ticks » while those exposed in the spring-summer months of April-September as « summer-ticks ».

Once weekly, the ticks were examined and the following data recorded : oviposition, egg hatching, larval and nymphal moultings and longevity of the unfed larvae, nymphs and adults. Larval mortality was declared 100 p. 100 when none were found to be moving around. Dead nymphal and adult ticks were checked individually.

Meteorological information

Twenty four hour temperatures were recorded at the experimental site using a Casella thermograph set on the ground close to the cylinders. Daily records of relative humidity and rainfall were retrieved from the monthly agroclimatological reports of the Israel Meteorological Service, situated in Beit-Dagan, about 3 km from the experimental site.

TABLE I Number of *Hyalomma anatolicum excavatum* ticks exposed in nature and in the incubator (laboratory control) Beit-Dagan, 1975-1977

Group of ticks	Months of exposure	Number of engorged ticks exposed :					
		Nature			Incubator (laboratory control)		
		Larvae	Nymphs	Females	Larvae	Nymphs	Females
"Winter"	October - November	1 500	300	30	500	75	3
	December - January	3 100	540	51	1 000	160	14
	February - March	3 000	600	60	673	200	22
"Summer"	April - May	1 800	300	60	600	120	10
	June - July	1 500	500	49	450	160	10
	August - September	2 900	600	60	880	185	14
Total		13 800	2 840	310	4 103	900	73

RESULTS AND DISCUSSION

The meteorological records for the 3 year period of the study are given in figure 1. The values obtained for each month during the 3 years of observation (1975-1977) were very similar, consequently the observations were grouped by month as one year study.

a) *Oviposition.*

The results are summarized in table II. It can be seen that the duration of the pre-oviposition period was closely related to the time period of detachment and exposure of the engorged females. « Summer ticks » (engorging and exposed during the months of April-September) laid eggs within 12-16 days in average post-detachment whereas « winter ticks » (engorging and exposed during the months of October-March) had much longer pre-oviposition periods i.e. 99-173 days in average. Similar results were recorded by BERDYEV (7). FELDMAN-MUHSAM (11), working with *Hyalomma savignyi* (= *H. excavatum*) females collected in November, found that those exposed under room and out-door conditions started oviposition 131-196 and 200-

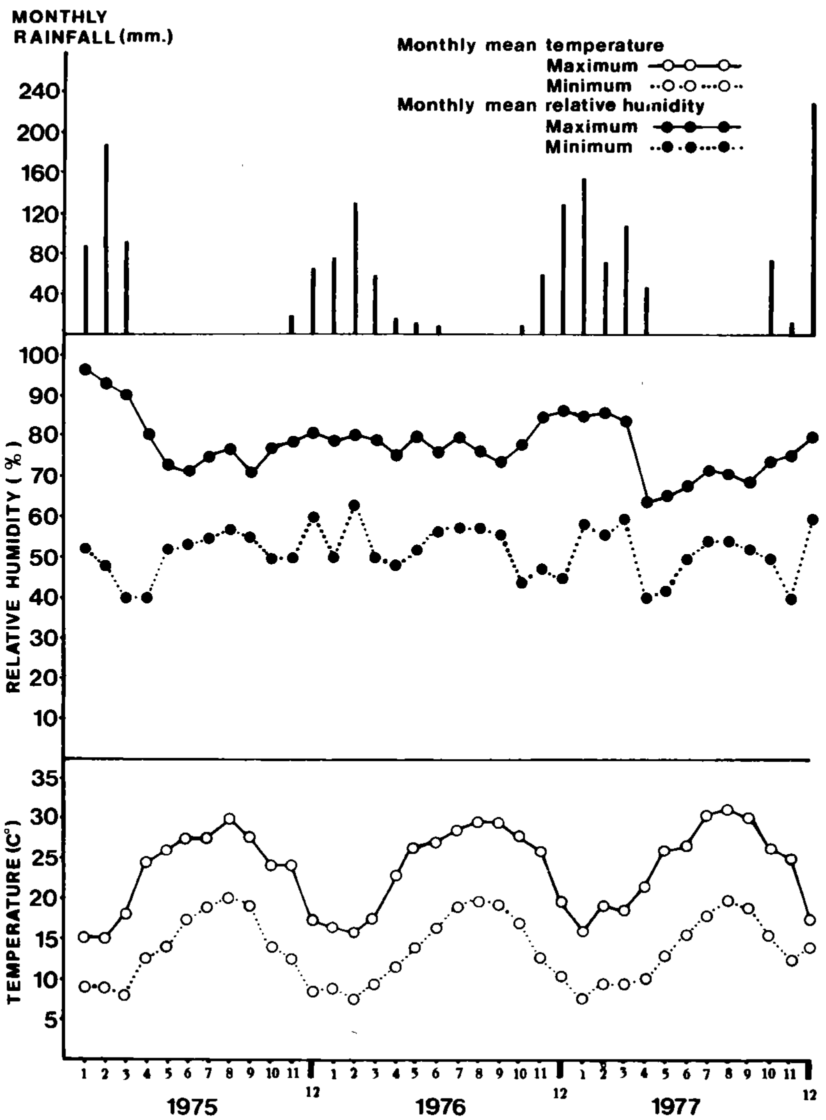

Figure 1. — Monthly mean temperatures (*), relative humidity (**) and rainfall (**) recorded in Beit-Dagan in 1975-1977.

(*) Recorded at the experimental site.
(**) Kindly supplied by the Israel Meteorological Service.

TABLE II-Rates of oviposition of *Hyalomma anatolicum excavatum* engorged female ticks and duration (in days) of preoviposition, prehatching and longevity periods of unfed larvae exposed in nature and in the incubator (Beit-Dagan, 1975-1977)

Group of ticks	Months of exposure of engorged females	Nature								Incubator (laboratory control)					
		Months of oviposition (starting)	Preoviposition period **	Ticks ovipositing (p.100)***	Ticks producing viable eggs (p.100) ***	Viability of batches of eggs (p.100)****	Months of larval hatching (starting)	Prehatching period**	Larval longevity**	Preoviposition period**	Ticks ovipositing (p.100) ***	Ticks producing viable eggs (p. 100) ***	Viability of batches of eggs (p.100) ****	Prehatching period**	Larval longevity**
"Winter"	October-November	April May*	173.9±13.9	76.6	3.3	4.3	June July	66.0	42.0	12.0±1.0	100	100	100	28.0±4.5	26.0±2.7
	December January	April May	137.3±21.3	45.0	3.9	8.6	June July	72.4+15.5	36.0±8.7	23.3±3.3	50.0	42.8	90.0	26.1±9.7	24.5±5.6
	February March	May June	99.0±16.9	30.0	11.6	38.8	July August	53.5±16.6	28.3±5.5	11.5±3.2	75.0	75.0	100	27.4±3.5	24.0±2.4
"Summer"	April May	April May	15.8±2.2	11.6	11.6	100	June July	48.8±8.0	106.0±15.8	8.7±3.5	80.0	80.0	100	27.8±3.9	41.7±3.7
	June July	June July	14.3+4.3	36.7	28.5	77.7	July August	35.0+6.4	80.3+34.2	8.6+3.4	90.0	80.0	88.8	20.0+6.4	50.2+2.2
	August September	August September	11.9+2.6	48.4	26.6	55.1	Septemb. October	32.4+7.0	114.7+20.4	9.4+3.7	78.5	78.5	100	23.6+5.1	24.5+2.5

* next year ; ** mean ± SD ; *** from total engorged females exposed ; **** from total batches of eggs produced.

210 days post-detachment respectively. Ticks similarly collected and maintained at 32 °C and 80 p. 100 RH (light regime not specified) laid eggs within 4-26 days. This author related the observed egg laying inhibition to the low temperature (16 °C) prevailing. Under laboratory conditions, egg laying in this tick species has been shown to occur at 15 °C and above (21) while BERDYEV (7) recorded a threshold temperature of 19,7 °C under natural conditions. In our trials, the lowest temperatures were registered in the months of December-March (fig. 1). Female ticks exposed during the months of November-March showed long pre-oviposition periods. Unpublished results (HADANI, ZIV in preparation) showed that raising the ambient temperature to 27 °C did not induce egg laying in such reproductively inhibited ticks. Oviposition started only when the engorged ticks were exposed to a continuous light.

Furthermore, in the present trials pre-oviposition periods registered in the control batches kept at 29 °C and continuous light ranged between 8-23 days throughout the year. In our laboratory, engorged *H.a.e.* females, bred in automn-winter months and maintained in continuous darkness in the incubator, usually manifest reproductive inhibition. It thus seems that the observed egg laying inhibition in *H.a.e.* might be essentially photoperiodism dependent, i.e. shortening of day length in the automn-winter months. Temperature might play a secondary role, forcing the ticks into non-specific, generalized physiological inactivity or torpor, well known in the case of *Boophilus microplus* (20). Egg laying diapause has been described in other ixodid species (2, 4, 22). RAZUMOVA (22) showed the existence of both potential diapause and inactivity in engorged *Dermacentor pictus (= D. reticulatus)* females. Such a dual control mechanism regulates the seasonal distribution of the highly susceptible pre-imaginal stages of this tick species incapable of over-wintering.

In our trials, relative humidity with a monthly average ranging between 55-75 p. 100 could not be shown to affect the process of oviposition. KUMAR and RUPRAH (21) recorded oviposition in *H.a.e.* at as low as 20 p. 100 RH.

Percentage of engorged female ticks that produced eggs in the control batches was high ranging between 50-100 p. 100, as compared to 12-77 p. 100 in those exposed to natural conditions. Furthermore, percentage of exposed female ticks producing viable eggs was still lower particularly in the reproductively inhibited « winter ticks » i.e. 3,3-12 p. 100 as against 12-29 p. 100 and 43-100 p. 100 in the « summer ticks » and control batches respectively. These findings might partly explain the difficulties encountered in maintaining a colony of *H.a.e.* going through the winter.

b) *Egg hatching*

The duration of the pre-hatching period, as measured from the beginning of oviposition, of the batches of eggs produced by the « summer ticks » ranged between 32-49 days while in the group of the « winter ticks » 54-72 days in average were recorded (Table II). BERDYEV (7) in Turkmenia showed that the pre-hatching periods in May and September were 14-28.5 and 33-35 days respectively. Eggs produced after September dried up during winter. Egg hatching in our control batches of eggs occurred 20-28 days post-oviposition. KUMAR and RUPRAH (21) recorded a pre-hatching period of 14-27 days at 25-40 °C and 66-73 days at 15-18 °C. Egg hatching didn't take place at a temperature below 15 °C and 20 p. 100 RH.

c) *Larval longevity*

The findings on the longevity of unfed larvae (time period from egg hatching until no larvae could be seen moving around) are summarized in table II. Larvae issuing from « summer ticks » survived in average 80-115 days as against 28-42 days observed in larvae issuing from female ticks exposed during the October-March period (« winter ticks »). It was found in our trials that unfed larvae didn't over-winter. SONENSHINE and ZIV (25) trapping jirds *(Meriones tristrami)* in the northern Negev in Israel found the rodents frequently infested with larvae and nymphs of *H.a.e.* Larval infestation was found to be minimal or nul during the winter months (December-February). Infestation rate increased considerably in March and November. BERDYEV (7) similarly found that unfed larvae, kept under field conditions, survived 6-95 days but didn't over-winter. Larval longevity in the control batches ranged between 24-50 days throughout the year. FELDMAN-

MUHSAM (9) obtained higher values when maintaining unfed *H. savignyi (= H.a.e.)* larvae at 17.5 °C and 95 p. 100 RH. Survival periods were found to be markedly shorter when larvae were exposed to higher temperatures and lower RH values. Similar results were reported by KUMAR and RUPRAH (21).

Summarizing the above mentioned findings (fig. 2) one can conclude that the reproductive diapause, recorded in our trials in the « winter ticks » and the longer prehatching period of the eggs, result in the absence or scarcity of eggs and larvae of this tick species during the months of December-March when climatic conditions are harsh.

d) *Larval moulting*

The results are summarized in table III. It can be seen that under outdoor conditions engorged larvae were found to moult throughout most of the year with the exception of the coldest months of January and February. The length of the larval premoulting period was found to be related to the period of exposure i.e. 9-13 days in the months of April-September as opposed to 51-89 days in average in the months of October-March.

Similar delayed metamorphosis in engorged larvae has been reported in other species of ticks (3, 5) where a combined effect of temperature and daylength has been incriminated.

BERDYEV (7) in Turkmenia obtained similar results with larval moulting taking place at a minimal temperature of 15.3 °C. KUMAR and RUPRAH (21) in laboratory trials reported a similar threshold temperature while FELDMAN-MUHSAM (10) noted larval moulting within 4-6 and 30-50 days post-exposure when maintained at ambient temperatures of 38 °C and 17.5 °C respectively.

The percentage of larval moulting was lower in the winter months i.e. 21-80 p. 100 in average as against 82-100 p. 100 in the summer months.

Larvae in the control batches were found to moult within 6-15 days post-exposure with 100 p. 100 of larval moulting. Similar results were reported by SNOW (24).

e) *Nymphal longevity*

As shown in table III, unfed nymphs survived 18-49 days in average with no clear relationship to the month of exposure. In field studies carried out by SONENSHINE and ZIV (25) jirds have been found slightly infested with *H.a.e.* nymphs during the cold months of November-February. As postulated previously (16) such a nymphal winter activity, might have been limited to the burrows of these field rodents in which microclimatic conditions are more favorable to the development and survival of the free pre-imaginal stages of the tick (1, 27). BERDYEV (7) found that unfed nymphs can survive 14-90 days while 10 p. 100 of the ticks over-wintered with an average longevity of 193 days. FELDMAN-MUHSAM (9) reported an average longevity of unfed *H.a.e.* nymphs ranging between 7-149 days depending on the temperature and degree of RH. In the laboratory, KUMAR and RUPRAH (21) kept unfed

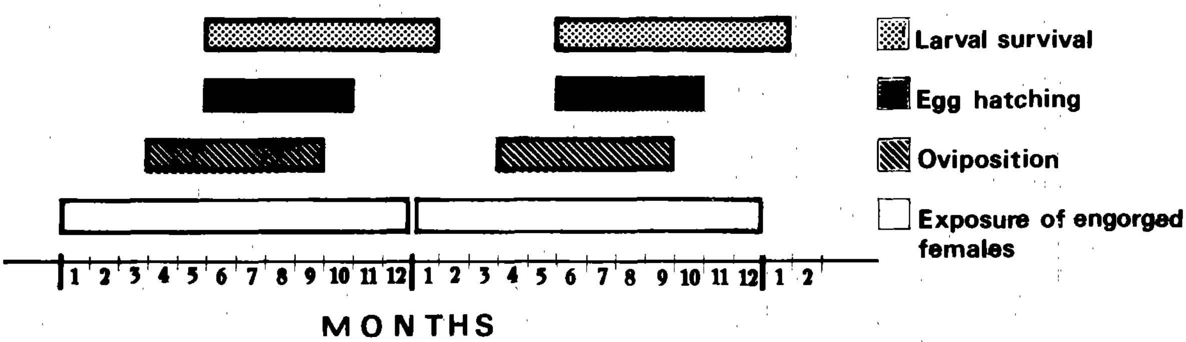

Figure 2. — Life cycle of *H.a. excavatum* with special reference to oviposition, egg hatching and larval survival (compiled from a three-year observation period).

TABLE III-Duration (in days) of larval premoulting and longevity periods of unfed nymphs of *Hyalomma anatolicum excavatum* maintained under natural conditions and in the incubator (Beit-Dagan, 1975-1977,

Group of ticks	Months of exposure of engorged larvae	Nature				Incubator (laboratory control)		
		Months of larval moulting	Premoulting period*	p.100 larval moulting	Longevity of unfed nymphs*	Premoulting period*	p.100 larval moulting	Longevity of unfed nymphs*
"Winter"	October November	November December	51.0±2.5*	31.3	36.8±13.5	10.0	100	54.0±7.8
	December January	March April	89.1±8.5	20.5	23.5±4.3	8.0±1.0	100	28.7±5.1
	February March	April May	51.2±16.9	80.0	28.6±7.1	11.5±5.5	100	34.0±7.2
"Summer"	April May	April May	8.6± 3.5	100	18.7±3.5	6.0	100	35.1±9.1
	June July	June July	13.1± 3.4	100	48.6±11.3	13.0	100	43.5±7.1
	August September	August Septemb.	11.5± 3.4	82.0	49.2± 7.2	14.5±3.5	100	43.0±5.8

* mean ± SD

H.a.e. nymphs alive for 228 and 12 days at 18 °C and 80 p. 100 RH and 37 °C and 30 p. 100 RH respectively.

In our control sets nymphal survival ranged between 29-54 days in average throughout the year. Similar findings were reported by SNOW (24).

f) *Nymphal moulting*

The results are presented in table IV. Length of nymphal pre-moulting period was closely related to the period of exposure, ranging between 23-26 days for the months of April-September (« summer nymphs ») and

TABLE IV-Duration (in days) of nymphal premoulting and longevity periods of unfed adults of *Hyalomma anatolicum excavatum* maintained under natural conditions and in the incubator (Beit-Dagan, 1975-1977)

Group of ticks	Months of exposure of engorged nymphs	Nature				Incubator (laboratory control)		
		Months of nymphal moulting	Premoulting period*	p.100 nymphal moulting	Longevity of unfed adults*	Premoulting period*	p.100 nymphal moulting	Longevity of unfed adults*
"Winter"	October November	April May**	159.0±17.8*	10.0	106.0± 9.6	29.0±2.3	100	331.0± 6.9
	December January	May June	153.0±39.3	11.6	78.8±20.1	19.4±0.5	80.0	181.8±13.9
	February March	May June	92.8±10.1	37.0	147.4±52.0	29.4±3.9	100	260.2±43.2
"Summer"	April May	May June	23.2±4.3	42.6	303.5±136.9	19.7±1.1	100	346.0±91.0
	June July	July August	25.9±3.4	65.8	403.5±86.0	20.5±2.5	100	217.3±12.6
	August September	Septemb.	23.5±3.3	73.5	233.9±70.5	18.0±1.6	100	274.2±16.9

* mean ± SD ; ** next year.

93-159 days in average for those of October-March (« winter nymphs »). Consequently, newly moulted adult ticks almost exclusively appeared in the months of April-September. Russian authors (1, 6) related such a delayed nymphal metamorphosis to the existence of diapause in the fall-winter detached engorged nymphs. Mortality rate in the « winter nymphs » was high with only 10-37 p. 100 of the nymphs actually moulting as against 43-74 p. 100 nymphal moulting in the months of April-September. According to BERDYEV (7) nymphal moulting takes place at a minimal temperature of 17.8 °C. In our control batches, the rate of nymphal moulting was high (80-100 p. 100) with a pre-moulting period of 18-29 days. Similar results were obtained by SNOW (24). KUMAR and RUPRAH (21) reported nymphal pre-moulting periods of 8.5-43 and 90-101 days at temperatures of 19-40 °C and 15 °C respectively.

g) *Longevity of unfed adult ticks*

As shown in table IV, the longevity of the unfed adult ticks was closely related to the period of the nymphal moulting and exposure, namely 78-147 days in average in the « winter adults » as compared to 234-404 days in the « summer » ones. The relationship was found statistically significant (r = 0,65). Unfed adult ticks over-wintered successfully sometimes surviving two winter seasons with a longevity of 665-706 days. BERDYEV (7) reported unfed adults ticks to survive 298 days (the duration of the experiment). Average longevity of unfed adults in the control batches was found to range between 182-346 days. Similar results were reported by FELDMAN-MUHSAM (12) who found the survival period to range between 87-132 days and 1-2 years at temperatures of 32-37 °C and 17.5 °C respectively and by KUMAR and RUPRAH (21). Based on the above mentioned results obtained in the field with « summer ticks » and findings compiled from previous studies (14) the life cycle of *H.a.e.* under laboratory conditions will be the following (average and range in days) :

Female ticks feeding on rabbits	12 (10-18)
Pre-oviposition period	14 (7-24)
Egg pre-hatching period	38.7 (21-54)
Larval pre-feeding period	15 (10-20)
Larvae feeding on jirds	7 (3-9)
Larval pre-moulting period	11 (6-14)
Nymphal pre-feeding period	11 (6-16)
Nymphs feeding on jirds	7 (6-14)
Nymphal pre-moulting period	24.2 (19-29)
Female pre-feeding period	24 (21-25)
Total	163.9 (109-223)

Length of one generation, obtained similarly from the control batches in the present study was 144 days in average. BERDYEV (7), working under field conditions, obtained similar results and under laboratory conditions life cycle was completed within 166 days (10) and 112.5 days (21). Findings of various other authors, compiled by SNOW (24), agree closely with ours.

Analyzing the life cycle of *H.a.e.* under field conditions, the following factors should be taken in account : difficulties in host finding particularly on the part of the larvae and adults, reproductive diapause and delay in larval and nymphal metamorphosis. Such delayed developmental phenomena have considerable biological advantage. They, in fact, ensure seasonal regulation, synchronous activity of developmental stages belonging to various tick generations and scarcity of the less resistant pre-imaginal stages when environmental conditions are hostile. It seems that the observed reproductive diapause can be broken down by maintaining the ticks in continuous light as has been shown in our control batches of ticks. The phenomenon of diapause in *H.a.e.* deserves further studies particularly with respect to possible existence of an endogenous physiological mechanism and the role played by environmental factors such as temperature and daylength. Considering our findings, *H.a.e.* under natural conditions in Israel might complete one generation in 1-2 years.

These findings should be taken in account in the planning of tick control operations, particularly with regard to strategic acaricidal applications.

SUMMARY

The life cycle of *Hyalomma anatolicum excavatum (H.a.e.)* has been studied under natural conditions with particular reference to pre-oviposition, egg hatching, larval and nymphal moultings and longevity periods of unfed larvae,

nymphs and adults. Ticks exposed during the months of October-March (« winter ticks »), had a protracted life cycle mainly due to egg laying inhibition in the engorged females and delayed larval and nymphal moultings. The duration of egg hatching was also longer than that found in the ticks exposed during the period of April-September (« summer ticks »).

Rate of oviposition and percentage of engorged females producing viable eggs was much lower in the « winter ticks » group as compared to the « summer » ones. Similarly the rate of larval and nymphal moultings was lower and the longevity of the freshly moulted larvae, nymphs and adults shorter in the « winter ticks » group as compared to the « summer ticks ».

A combined effect of daylength and temperature seems to regulate the above mentioned biological processes as a result of which pre-imaginal stages are scarce or absent in the harsh winter season, whereas adults are active mainly in summer. Under field conditions in Israel, *H.a.e.* would be likely to complete one generation in 1-2 years. These findings should be considered in the planning of tick control measures.

RESUMEN

El ciclo de vida de la garrapata *Hyalomma anatolicum excavatum* Koch, 1844, mantenida en condiciones naturales en Israel

El ciclo de vida de la garrapata *Hyalomma anatolicum excavatum (H.a.e.)* ha sido estudiado en condiciones naturales, particularmente en lo que respecta a la pre-oviposición, eclosión de huevos, mudas de larvas y ninfas y a la sobrevivencia de larvas, ninfas y adultos en inanición. Las garrapatas que fueron expuestas durante los meses de octubre-marzo (« garrapatas de invierno ») demostraron un ciclo de vida de mayor extension, debido principalmente a la inhibición de la oviposición en garrapatas hembras repletas y al retraso de la muda larval y ninfal. La duración de la eclosión de huevos fué también mas larga que aquella observada en garrapatas expuestas durante el período abril-setiembre (« garrapatas de verano »).

La incidencia de la oviposición y el porcentage de hembras produciendo huevos vitales fueron mucho más bajos en « garrapatas de invierno » que en las « de verano ». Similarmente, la incidencia de las mudas larval y ninfal fué menor y la sobrevivencia de larvas, ninfas y adultos recién mudados fué mas corta en garrapatas « de invierno » que en las « de verano ».

Los procesos biológicos anteriormente mencionados parecen estar regulados por el efecto combinado de fotoperiodicidad y temperatura, con el resultado de que los estadios pre-imaginales son escasos o ausentes durante la estación dificil del invierno. Los adultos son activos principalmente durante el verano.

En condiciones de campo, estudiados en Israel, *H. a. e.* podria probablemente completar una generación en uno a dos años. Estos hallazgos debieron ser considerados en la planificación de sistemas de control de las garrapatas.

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