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## Effects of Humidity on Development and Growth in the Tick, *Haemaphysalis longicornis*

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The cattle ticks in all developmental stages were reared at controlled humidities (59.5, 75.5, 84.5 and 100% RH) and at a constant temperature of 30°C. The hatch-ratio increased conspicuously as the humidities became high, but the average incubation period was merely slightly shortened. The larval moulting ratio at 100% RH was very high compared with that at 84.5% RH ; however, there was no significant difference in the average moulting period between both RH conditions. Every nymphal moulting ratio was generally high and the average moulting period at each humidity was almost constant. Only one of the three engorged females could oviposit at 59.5% RH ; the number of the deposited eggs per mg of the body weight at 75.5% RH and below did not reach the mean number for the body weight at 100% RH. The survival period of unfed ticks in each stage at 75.5% RH and below was within two weeks, but as a whole, the survival periods were lengthened and the survival ratios heightened with increasing humidity. Thus, it is concluded that low humidities are more harmful to the earlier developmental stages and the lowest humidity for tick survival is between 84.5% and 75.5% RH, and that high humidities above 84.5% RH are necessary to complete the life cycle.

### INTRODUCTION

The humidity of the environment is of paramount importance in the life cycle of ticks. The critical equilibrium humidity at which the unfed ticks can maintain the body water balance by means of absorbing water vapor from the atmosphere is generally high, being between 70% and 96% RH (Kniille and Rudolph, 1982).

In *Haemaphysalis longicornis*, however, there has no determination of the lowest humidity for the survival of various stages, except for some occasional reports concerning the effects of humidity on hatching of the eggs (Namba, 1953 ; Heath, 1979), moulting of the engorged larvae (Heath, 1981) and oviposition (Fujisaki *et al.*, 1975). As a basis for the control of *H. longicornis*, the most dominant tick on Japanese pasture, we examined the life cycle in the laboratory (Yano *et al.*, 1985) and the effects of temperature on the development and growth (Yano *et al.*, 1987). The purpose of the present study was to elucidate the effects of humidity on the development and the survival of the tick in all developmental stages, and to estimate the lowest humidity for the development and survival.

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## MATERIALS AND METHODS

The ticks, *H. longicornis* (the bisexual strain) were collected by the flagging method on a pasture at Kujū Highland, Ōita Prefecture, in mid-June 1985 and 1986. The eggs were taken from the egg masses laid by three engorged females in the laboratory. The unfed larvae, nymphs and females were fed to engorgement on the rabbits. The unfed larvae, which hatched under laboratory conditions and became active five days after hatching, and unfed nymphs as well as adults (♂, ♀), both of which were captured on the pasture, were used for survival experiments.

The eggs and the ticks in various developmental stages (the unfed larva, engorged larva, unfed nymph, engorged nymph, unfed male and female, and engorged female) were put into plastic cases (3X6X1.5 cm) or glass tubes (ht. 4 cm, dia. 1.5 cm) which were covered up by gauze and placed in desiccators with four different humidities as follows : 59.5% RH (NH<sub>4</sub>NO<sub>3</sub>), 75.5% RH (NaCl) and 84.5% RH (KCl); each humidity was maintained by using about 300 ml of the saturated solutions (Winston and Bates, 1960), and 100% RH was kept by putting a filter paper soaked continuously with water into the above cases and glass tubes. All humidities were checked twice a month by a hygrometer ( $\pm 3\%$ ). The desiccators were placed in an incubator kept at a constant temperature of 30°C. The eggs were left in the desiccators to hatch, and the ticks to moult and oviposit and then to be determined survival. The number of the eggs and the ticks used in the experiments are summarized in the tables.

## RESULTS

### 1. Hatching of the eggs (Table 1)

The eggs hatched at 75.5% RH and above ; the hatch-ratio conspicuously increased from 1.0 to 97.0% with rising humidity. The average incubation period, however, merely slightly shortened from 22.3 to 17.3 days.

### 2. Moulting of the engorged larvae and nymphs (Table 2)

The engorged larvae did not moult at the low humidities (59.5% and 75.5% RH) and the moulting ratio at 100% RH (88.0%) was very high compared with that at 84.5% RH (27.3%) ; however, the average moulting period did not differ significantly between both the RH conditions (12.2 days at 84.5% RH and 11.4 days at 100% RH).

**Table 1.** Egg hatchability at constant relative humidities and 30°C in *Haemaphysalis longicornis*.

Relative humidity (%)	N	Hatch-ratio (%)	Incubation period (days)	
			average	range
59.5	300	0	—	—
75.5	300	1.0	22.3	22-23
84.5	300	38.0	21.0	20-23
100	300	97.0	17.3	15-23

On the other hand, the engorged nymphs moulted at all humidities, every moulting ratio was high (85.7-100%) and the average moulting period at each humidity was almost constant (10.2-11.7 days).

**Table 2.** Moulting of engorged larvae and nymphs at constant relative humidities and 30°C in *Haemaphysalis longicornis*.

Relative humidity (%)	Larval moulting				Nymphal moulting			
	N	Ratio (%)	Period (days)		N	Ratio (%)	Period (days)	
			average	range			average	range
59.5	22	0	—	—	7	85.7	11.7	10–13
75.5	22	0	—	—	10	100.0	11.0	10–13
84.5	22	27.3	12.2	10–16	10	90.0	11.1	10–16
100	25	88.0	11.4	8–18	25	92.0	10.2	9–12

**Table 3.** Oviposition at constant relative humidities and 30°C in *Haemaphysalis longicornis*.

Relative humidity (%)	Preoviposition period in days (average)			Oviposition period in days (average)			Number of eggs deposited per mg body weight (average)		
59.5	4	5	—	8	14	—	7.7	—	—
75.5	4	(5.0)	6	10	(14.0)	18	6.8	7.6	8.6
		4			14			(7.7)	
84.5	4	(4.3)	5	9	(13.7)	18	9.4	9.6	11.6
		5			19			(10.2)	
100	4	(4.7)	5	18	(19.0)	20	11.1	11.8	11.8
								(11.6)	

The number of the engorged females used at each humidity is three.

### 3. Oviposition (Table 3)

The engorged females deposited eggs at all humidities after almost constant preoviposition periods (4-6 days), except for two of the three females at 59.5% RH. The average oviposition period was prolonged at high humidities (from 8 to 19.0 days); the number of the deposited eggs per mg of the body weight became heightened (from 7.7 to 11.6) with increasing humidity.

### 4. Survivability of the unfed ticks (Table 4, Fig. 1)

The survival periods at 84.5% RH and higher humidities were significantly longer than those at 75.5% RH and below; at 75.5% RH and below all ticks died within 14 days. At the same humidity, there was no significant difference in the survival period between larvae and nymphs, while a conspicuous disparity was noted between the above two and the adult which lived for a long period (Table 4).

Concerning the pattern of the survival curve in each stage, the survival ratio of the unfed ticks in the various developmental stages (the larva, nymph and adult) increased with rising humidity, and decreased rapidly and in a straight line at 75.5% RH and below, but at 84.5% RH and above it nearly remained at a plateau for a different period according to the stage, subsequently was lowered gradually (Fig. 1). Since the survivability of the adult did not differ between both sexes, the data were dealt with *en bloc*.

Table 4. Survival of unfed larvae, nymphs and adults at constant relative humidities and 30°C in *Haemaphysalis longicornis*.

Relative humidity (%)	Survival period (days)								
	Larvae			Nymphs			Adults		
	N	average	range	N	average	range	N	average	range
59.5	66	1.9	1 - 3	20	2.1	1 - 4	20	2.7	1 - 5
75.5	100	2.7	1 - 5	20	3.8	1 - 7	20	8.8	1 - 14
84.5	68	24.8	1-40	21	23.8	4-41	20	53.4	2-107
100	59	56.7	28-70	50	59.0	26-94	48	144.9	30-242

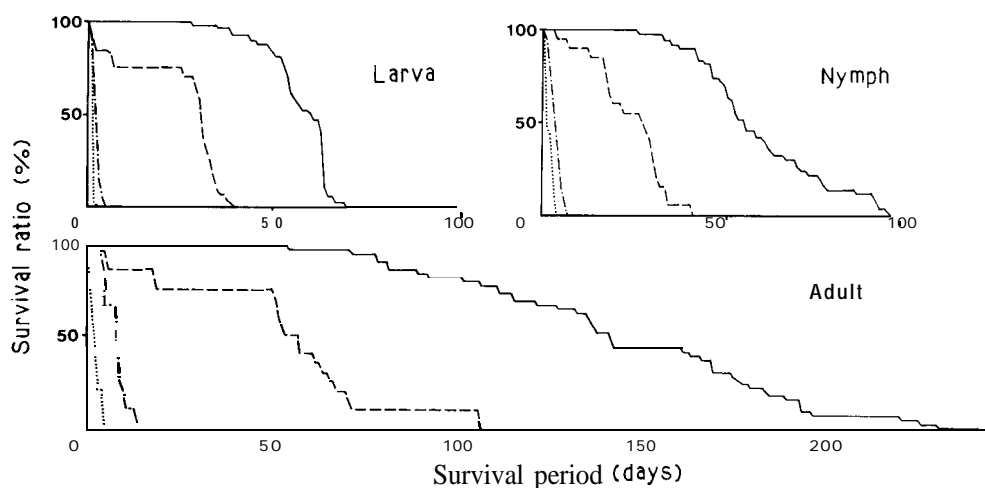


Fig. 1. Survivability curves of unfed larvae, nymphs and adults at constant relative humidities and 30°C in *Haemaphysalis longicornis*. ·····, 59.5% RH; - · -, 75.5% RH; ----, 84.5% RH; —, 100% RH

## DISCUSSION

The drought resistance in *H. longicornis* varied with the developmental stages. The low humidities were harmful especially to the earlier developmental stages. The

high ratios of hatching and larval moulting obtained at 100% RH were not achieved even at 84.5% RH (Tables 1 and 2). Since the number of the deposited eggs failed to reach the normal number corresponding to the body weight of the engorged tick at 75.5% RH and below (Table 3), the egg productivity also seems to be influenced by the low humidities. The humidities examined, however, had no effect on nymphal moulting, whose ratios were high even at the low humidities (Table 2). The survival periods were lengthened with increasing humidity, and the adult survived for a longer time than did the larva and nymph (Table 4 and Fig. 1).

The drought resistance in ticks varies also with the species, i. e. the lowest humidities for egg hatching are 75% RH, 45% RH, 60% RH, 56% RH and 33% RH in *Boophilus microplus* (Hitchcock, 1955), *Dermacentor variabilis* and *Amblyomma americanum* (Sonenshine and Tigner, 1969), *Boophilus decoloratus* and *Rhipicephalus evertsi* (Rechav and Maltzahn, 1977), respectively ; oviposition takes place normally at 40% RH and above in *B. microplus* (Hitchcock, 1955 ; Bennett, 1974), at 45% RH and above in *D. variabilis* and *A. americanum* (Sonenshine and Tigner, 1969) ; further, *Rhipicephalus sanguineus* (Sweatman, 1967) and *Hyalomma aegyptium* (Sweatman, 1968) can lay eggs even at 0% RH, and *Hyalomma anatolicum* (Snow and Arthur, 1966) at 25% RH.

Heath (1979, 1981) has reported the temperature and humidity suitability for egg hatching and larval moulting in the laboratory for three ticks (*H. longicornis*, *Ixodes holocyclus*, *R. sanguineus*) from Australia, and pointed out the correspondence between their temperature/humidity requirements and the climate within the geographic range of each species. *R. sanguineus* inhabiting the regions devoid of significant precipitation outside the wet season has the strongest drought resistance (hatching at 2-20 mm Hg saturation deficit, moulting at 2-35 mm Hg s. d. and a slow loss of water) ; on the contrary, *I. holocyclus* requires moderate temperatures and high moisture level for its survival and is poor in the drought resistance (unhatching at 4 mm Hg s. d. and over, moulting at 2-4 mm Hg s. d. and a rapid loss of water). Thus, the differences in the drought resistance of tick species might well reflect their habitats and geographic distributions, and especially the humidity conditions required for egg hatching and larval moulting.

Unfed ticks must absorb moisture from the atmosphere for water maintenance until they attach to hosts. Ticks die within a given short period at less than the critical humidity (Knülle and Wharton, 1964). The critical equilibrium humidities of various kinds of tick species are summarized by Knülle and Rudolph (1982). Although in *H. longicornis* experiments on the changes of the body weight for various humidities were not attempted, judging from a great disparity in the survival period in each developmental stage between 75.5% and 84.5% RH, it is suggested that the critical equilibrium humidity for *H. longicornis* is between them.

Nymphal moulting and oviposition occurred at 59.5% RH in *H. longicornis*, but both can take place at lower humidities, i. e. the former at 50% RH (Morii and Kitaoka, 1971) and the latter at 53% RH (Fujisaki, et al., 1975). Apart from this, it is concluded that the high humidities of 84.5% RH and over are necessary for the completion of the life cycle in *H. longicornis*, although the lowest humidity for the development and survival varied with the stages.

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