INFLUENCE OF TEMPERATURE ON THE REPRODUCTION OF *DAMALINIA EQUI* (DENNY)

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Summary

No development of the egg within the female *Damalinia equi* (Denny) occurred at 16°C. Most eggs were laid at 36°C at R.H.'s of 75% or less, but after an exposure to 44·5°C for only 1 hr females did not lay eggs. Morphogenesis proceeded to an advanced state from 27–39°C, but its completion and the subsequent hatching of the embryo only took place from 31–39°C provided the R.H. was less than 90%. A R.H. of 90% prevented hatching of the eggs. Exposure of eggs to 49°C for 2 hr was lethal.

The skin temperature of the horse is influenced considerably by atmospheric temperature. The abundance of *D. equi* on the bodies of horses in early spring is probably due to the temperatures near the skin of the body being continuously favourable for reproduction of *D. equi* during the winter. Exposure to the sun can cause the temperatures within the hair coat on the upper aspects of the body to become higher than 44·5°C for more than an hour and thus can retard reproduction. The accumulative effect of repeated high temperatures could prevent an increase in the numbers of *D. equi* during the summer.

I. INTRODUCTION

The influence of temperature and humidity on oviposition has been reported previously (Murray 1957), and the present paper is concerned with their influence on other aspects of the biology of *Damalinia equi* (Denny), the biting louse of the horse, which are related to reproduction. Few males of *D. equi* have ever been found, and the female reproduces parthenogenetically throughout the year. A study of the influence of microclimate on its reproduction is therefore simplified because no consideration has to be given to effects on spermatogenesis and mating behaviour. The methods were as used in previous studies (Murray 1957, 1960).

II. INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF THE EGG WITHIN THE FEMALE

(*a*) *Low Temperatures*

The length of eggs inside females was determined as previously (Murray 1957). Female lice were divided into two groups of similar numbers containing eggs at similar stages of development. Both groups were exposed to 54% R.H. at 16°C, a temperature frequently encountered on the lower parts of the limbs of horses in cold weather (Okabe, Sugiyama, and Ohi 1958), and the length of the egg was remeasured 24 hr later. One group was then returned to 16°C and the other exposed to 35°C at 54% R.H. After a further 24 hr the length of the eggs was again remeasured. There was little increase in the length of the egg within females exposed to 16°C, but when they were exposed to 35°C there was a considerable increase (Table 1).

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(*b*) *High Temperature*

Groups of females were exposed to 44·5°C at 54 and 88% R.H. for ½, 1, 2, or 3 hr, after which they were exposed to 35°C at 54% R.H. The number of eggs laid was counted 48 hr later. Control groups were exposed to 35°C at 54% R.H. throughout this period. Table 2 shows that an exposure of 3 hr to 44·5°C at 54% R.H. killed the lice. An exposure of 2 hr at both 54 and 88% R.H. killed many lice and affected the remainder so that no eggs were laid subsequently. Even an exposure of only 1 hr affected the activity of many lice and caused a marked reduction in the number of eggs laid, particularly by the lice exposed to 54% R.H.

Other groups of lice were exposed to 42°C at 54% R.H. for 4, 8, or 15 hr. A reduction in the number of eggs laid occurred only after an exposure of 15 hr.

TABLE 1
INFLUENCE OF TEMPERATURE ON THE DEVELOPMENT OF THE EGG WITHIN FEMALE D. EQUI

Egg Length (mm)	Increase in Egg Length (mm) after 24 Hr at 16°C	Additional Increase in Egg Length (mm) after a further 24 Hr at 16°C	Egg Length (mm)	Increase in Egg Length (mm) after 24 Hr at 16°C	Additional Increase in Egg Length (mm) after a further 24 Hr at 35°C
0·40	0	0	0·40	0	0·16
0·53	0·025	−0·025	0·45	0·025	0·16
0·53	0·16	0·05	0·53	0·025	−0·025
0·61	0·05	0	0·80	0·025	0·13
0·7	0	−0·025	0·53	0	0·11
0·72	0·08	0·08	0·58	0	0·16
0·75	0·05	0	0·70	0	0·18
0·75	0	0·05	0·72	0·025	0·11
0·83	0	0·025	0·72	0·05	0·18
0·83	0	−0·025	0·80	0·025	0·13
0·83	−0·025	0	0·88	0·025	0·13
0·83	0·025	−0·025	0·88	0	0·13
Mean	0·03	0·013	Mean	0·017	0·134

III. INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE NUMBER OF EGGS LAID

It has been shown previously that at 60% R.H. *D. equi* lays most eggs in the temperature range 32–38°C (Murray 1957), but the influence of humidity was not determined.

Lice were divided into 15 groups, each of which was placed in a glass tube with glass wool. Five groups were exposed to each of the temperatures 31, 36, or 39°C and one group of each lot of five was exposed to 33, 54, 75, 92, and 100% R.H. The number of eggs laid in 40 hr was determined. Most were laid at 36°C, but the lice exposed to 92 and 100% R.H. laid fewer eggs than those exposed to 33–75% R.H. Many more eggs were laid at 39 than at 31°C, and at 39°C fewer eggs were laid by the lice exposed to R.H.'s of 75–100% (Table 3).

TABLE 2
INFLUENCE OF SHORT EXPOSURE TO HIGH TEMPERATURE ON THE NUMBER OF EGGS LAID BY D. EQUI WHEN SUBSEQUENTLY EXPOSED TO 35°C AT 54% R.H.

Temp. (°C)	R.H. (%)	Duration of Exposure (hr)	State of Lice after Exposure	Number of Lice	Number of Eggs Laid Subsequently at 35°C	Eggs per 100 Females (%)
35	54	48	Vigorously active	136 172 121	48 54 40	36 31 33
				429	142	33
44·5	54	0·5	Vigorously active	142	27	19
		1	Sluggishly active, some inactive	170 144 150	1 2 15	0·6 1·4 10
				464	18	4
		2	In heat stupor or dead	157	0	0
		3	Dead	103	0	0
44·5	88	1	Sluggishly active, some inactive	140 102 136	17 14 25	12·1 13·7 18·4
				378	56	14·8
		2	In heat stupor or dead	145	0	0

TABLE 3
INFLUENCE OF TEMPERATURE AND HUMIDITY ON THE NUMBER OF EGGS LAID BY D. EQUI

Temp. (°C)	33% R.H.		54% R.H.		75% R.H.		92% R.H.		100% R.H.	
	No. of Females	No. of Eggs	No. of Females	No. of Eggs	No. of Females	No. of Eggs	No. of Females	No. of Eggs	No. of Females	No. of Eggs
31	1030	32	1200	5	1160	0	1160	1	1040	0
36	1100	217	1250	192	1300	169	1400	67	1100	28
39	1060	95	1300	115	1200	10	1260	4	1160	5

IV. Influence of Temperature and Humidity on the Development and Hatching of Eggs

Lice were removed from a horse and placed in glass tubes with glass wool. They were exposed to 35°C at 54% R.H., and the eggs laid within 24 hr were exposed to various temperatures and humidities for 3 weeks to allow sufficient time for those exposed to the lowest temperature to hatch.

It was not possible to collect sufficient eggs at any one time to expose them simultaneously to all the combinations of temperature and humidity desired. The experiment was therefore carried out in stages and some eggs from each collection

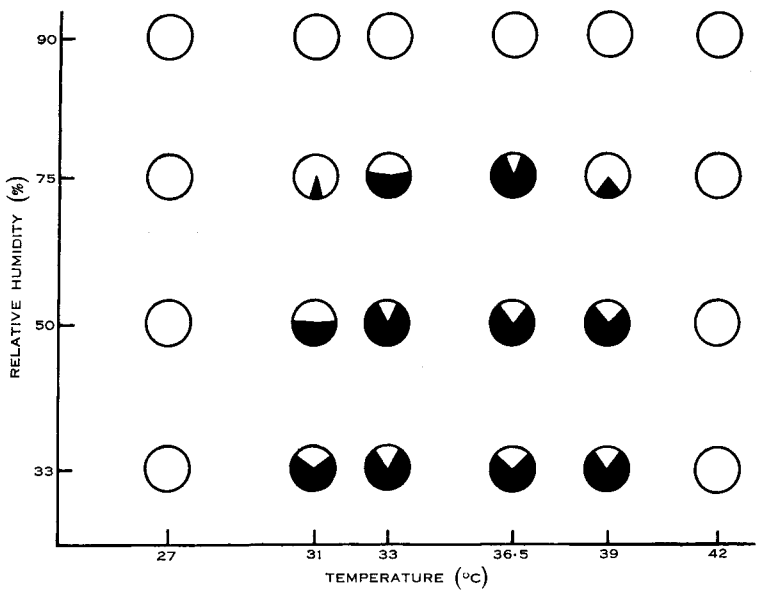

Fig. 1.—Influence of temperature and humidity on percentage of eggs of *D. equi* completing development and hatching. The shaded areas represent the percentage of eggs which hatched.

were exposed to 35°C at 54% R.H. as a control. The remainder were divided into groups of equal number and exposed to 27, 31, 33, 36, 39, and 42°C. At each temperature a group was exposed to R.H.'s of 33, 54, 75, or 90%. At least 50 eggs were exposed to each combination of temperature and humidity except for 42°C, where 17–24 eggs were exposed to each R.H. All unhatched eggs were examined to determine the number in which morphogenesis was well advanced, and they were then exposed to 35°C at 54% R.H. to determine whether they would continue their development and hatch, but all were found to be dead. Figure 1 shows that eggs of *D. equi* completed their development and hatched in the temperature range 31–39°C at R.H.'s of 33–75% but no eggs hatched at 90% R.H. although in many morphogenesis was well advanced and the embryo was nearly fully developed. Eggs did not hatch at

either 27 or 42°C. Morphogenesis was well advanced in many of the eggs exposed to 27°C but not in those exposed to 42°C (Fig. 2).

V. Influence of High Humidity on Hatching of Eggs

Lice were placed on glass wool and exposed to 35°C at 54% R.H. for 24 hr. The eggs which were laid were mounted for study between thin white paper and a coverglass, and returned to 35°C at 54% R.H. On the ninth and tenth days the eggs were examined with transmitted light. The embryos of *D. equi*, like those of *D. ovis* (L.), turn fawn in colour during the last 24 hr of development (Murray 1960). Those which, on this basis, were expected to hatch within 24 hr were divided into groups

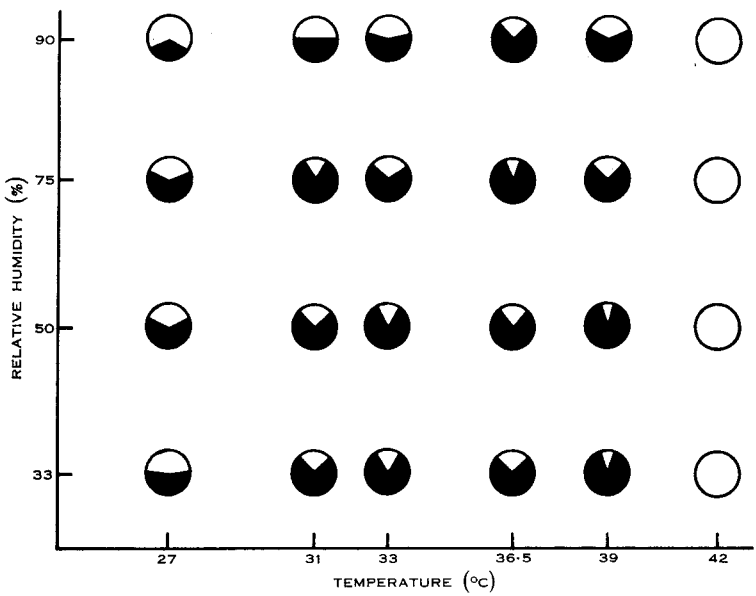

Fig. 2.—Influence of temperature and humidity on morphogenesis of eggs of *D. equi*. The shaded areas represent the percentage of eggs in which the embryo completed and nearly completed development.

and exposed to 35°C at 54, 85–92, or 92% R.H. Over 95% of 148 eggs exposed to 54% R.H. hatched, *c.* 60% of 105 exposed to 85–92% R.H. hatched, but only 10% of 59 at 92% R.H. High humidities therefore prevented eggs from hatching.

VI. Lethal Effect of High Temperature on Eggs

Eggs which were within 24 hr of hatching were exposed to temperatures of 42, 45, or 49°C at 75% R.H. for 1, 2, 4, or 6 hr. Afterwards they were returned to 35°C at 75% R.H., and the number of eggs which hatched was determined 24 hr later. None of the exposures to 42°C was lethal, only *c.* 50% were dead after 6 hr at 45°C, but all exposures over 1 hr caused 100% mortality at 49°C (Table 4).

VII. Influence of Solar Radiation on the Temperature within the Hair Coat of the Horse

A brown horse was kept for 3 days in a yard where there was no shade from the sun. The temperature within the hair coat was measured with a thermistor probe (accuracy $\pm$ 0·25°C) at intervals of half an hour for 3 hr during the middle of each day. The measurements were made during the summer (February) when the atmospheric temperatures ranged between 30 and 33°C.

It was found that within 1 hr, temperatures of 52°C were established in the tip of the hair coat on the withers, back, and rump. Here the hair coat was only $\frac{1}{8}$ in. thick, and temperatures of 44·5°C persisted for over 3 hr throughout the outer half. The skin temperature in these areas was 39–41°C.

There was, however, a gradient of temperatures over the body. The temperatures were highest on the withers, back, and rump, but were lower down the sides where the solar radiation was less intense.

Table 4
EFFECT OF SHORT EXPOSURES TO HIGH TEMPERATURE ON THE EGGS OF D. EQUI

Time of Exposure (hr)	42°C		45°C		49°C	
	No. of Eggs	No. Hatched	No. of Eggs	No. Hatched	No. of Eggs	No. Hatched
1	40	39	38	38	41	39
2	43	43	38	35	48	0
4	39	38	39	32	42	0
6	41	40	41	23	41	0

VIII. Discussion

The critical phases in the parthenogenetic reproduction of *D. equi* are the development of the egg within the female, oviposition, morphogenesis within the egg, and hatching. It was found that at a temperature of 16°C no development of the egg within the female took place and that exposure to 44·5°C for only 1 hr could prevent subsequent oviposition. Fewer eggs were laid at 31 than 39°C and most were laid between 32–37°C (Murray 1957). Morphogenesis proceeded to an advanced stage in over 50% of eggs at temperatures from 27–39°C but no embryos reached an advanced stage of development at 42°C. Only between 31 and 39°C did morphogenesis proceed to completion and hatching occur. At these temperatures hatching did not occur if humidities were high, as is the case with eggs of *D. ovis* (Murray 1960, 1963). Exposure of eggs in an advanced state of development showed that, whereas an exposure to 49°C for 2 hr was lethal, an exposure to 45°C for at least 6 hr was required before a high proportion of eggs was killed.

Okabe, Sugiyama, and Ohi (1958) reported extensive observations on the relationship between the skin temperature of 169 horses at atmospheric temperatures from −5 to 30°C. The temperature of the skin in the region of the hock and the knee was usually below 20, 25, or 30°C when the atmospheric temperature was 5, 10, or 20°C, respectively, whereas the skin temperature of the body was usually 30–35°C regardless of temperature of the atmosphere.

In the present study it was shown that exposure to solar radiation raises the temperature of the horse's coat and skin. Temperatures of 44·5°C and higher were established in less than an hour to within $\frac{1}{16}$ in. of the skin and persisted for over 3 hr.

Throughout the winter months, only the temperatures near the skin on the body are continuously suitable for the egg to develop within the female, for oviposition, and for egg development. This may well explain the presence of *D. equi* in large numbers on the bodies of horses at the end of winter in contrast with their scarcity on the limbs. On the other hand, during the summer months, the temperature within the hair coat covering the withers, back, and rump can become and remain sufficiently high to either kill lice, or to reduce the number of eggs laid. It seems likely therefore that the accumulative effect of high temperatures in the hair coat can become sufficiently severe to exert a marked adverse effect on a population of *D. equi*, and thus prevent an increase of their numbers during the summer months.

Matthysse (1946) reported temperatures of up to 52°C in the coats of cattle and suggested that a high skin temperature is the main factor limiting cattle lice during the summer. In the fleeces of sheep exposed to the sun in Queensland, temperature gradients from 40°C at the skin to 71°C at the fleece tip can become established within an hour (Murray 1957), and MacFarlane, Morris, and Howard (1958) have reported temperatures as high as 42°C at the skin and 89°C at the fleece tip. Taking into consideration these observations and the effect of high temperature on the reproductive ability of *D. equi*, it seems likely that solar radiation is a factor which can prevent increases of the number of lice in the summer on those species of large animals which live exposed to the weather, particularly where solar radiation is intense.

IX. References

MacFarlane, W. V., Morris, R. J. H., and Howard, Beth (1958).—*Aust. J. Agric. Res.* **9**: 217–28.

Matthysse, J. G. (1946).—Bull. Cornell Agric. Exp. Sta. No. 832.

Murray, M. D. (1957).—*Aust. J. Zool.* **5**: 183–7.

Murray, M. D. (1960).—*Aust. J. Zool.* **8**: 357–62.

Murray, M. D. (1963).—*Aust. J. Zool.* **11**: 173–82.

Okabe, T., Sugiyama, T., and Ohi, S. (1958).—*Jap. J. Zootech. Sci.* **29**: 122–8.

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