

Thermal Effect on the Life-cycle Parameters of the Medically Important Freshwater Snail Species *Lymnaea (Radix) luteola* (Lamarck)

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The snails Lymnaea (Radix) luteola exhibited marked variations in growth, longevity, and attaining sexual maturity at different temperatures and diets. At 10°C, irrespective of foods, pH and salinity of water, the snails had minimum life span, maximum death rate and lowest growth rate. At 15°C, the growth rate was comparatively higher and the snails survived for a few more days. But at these temperatures they failed to attain sexual maturity. Snails exposed to pH 5 and 9 at 20°, 25°, 30°, 35°C and room temperatures (19.6°-29.6°C); to 0.5, 1.5 and 2.5 NaCl ‰ at 20° and 35°C; to 2.5 NaCl ‰ at 25°C and room temperatures failed to attain sexual maturity. The snails exposed to pH 7 and different salinity grades at 20°, 25°, 30°, 35°C and room temperatures became sexually mature between 25-93 days depending upon the type of foods used in the culture.

Key words : *Lymnaea (Radix) luteola* - life-cycle parameters - temperature - food - pH - salinity - India

Lymnaeids are distributed worldwide (Godan 1983). They have drawn the attention of a large number of researchers because of their role as hosts for larval stages of the helminth parasites which cause disease in man and domestic animals (Liston & Soparkar 1918, Rao 1933, Chatterjee 1952, Malek & Cheng 1974, Ghosh & Chauhan 1975, Godan 1983, Burch 1985, Raut 1986). Considering their involvement in regulating the life-cycle of the worm parasites various aspects of the biology and ecology of these freshwater gastropod snails were studied by Seshaiya (1927), Noland and Carriker (1946), Kendall (1953), McCraw (1970), Berrie (1965), Burla and Speich (1971). Van der Steen et al. (1973), Hunter (1975) Raut et al. (1992), Raut and Misra (1993), and Misra and Raut (1993) with a view to developing methods for control. Although additional information on ecology of lymnaeids is available (Jong-Brink 1990, Moens 1991) an effective control device for these snail intermediate hosts has not been found. Since the status of individuals of a species is largely determined by the physical, chemical and biological parameters of the ecosystem to which they belong it is most likely that a study on the cumulative influence of these factors would provide us better information on the subject. As most of the

available information is based on the results of experimental studies considering only a single factor (Vaughn 1953, Prinsloo & Van Eden 1969, 1973, Van der Borgh & Van Puymbroeck 1971, Raut & Misra 1991, 1993, Raut et al. 1992, Saha & Raut 1992) it has not been possible to regulate the density of these snails through the application of these results. Accordingly, the present study was designed to collect detailed information on the life-cycle parameters viz., the growth rates, the age of attainment to sexual maturity, the duration of reproductive period, the rate of egg production, the death rate and the life span of *Lymnaea (Radix) luteola* (Lamarck), in order to consider the cumulative effects of these different ecological parameters. Since *Lymnaea* are adapted to a wide range of temperatures (Walter 1968, Prinsloo & Van Eeden 1969) the aim was to study the effect of temperature on the snails *L. (R.) luteola* under varying ecological conditions such as food, water pH and salinity (NaCl). The findings are presented herein.

MATERIALS AND METHODS

Eighty-one healthy, sexually mature *L. (R.) luteola* were collected from the pond located in the Ballygunge Science College campus, Calcutta University on 18 March 1991. They were released into an aquarium 30 x 20 x 25 cm, containing pond water, 20 cm in depth. A few examples of *Chara*, *Vallisneria* and *Ipomoea* were also released into the water of the aquarium to provide resting and egg laying sites for the snails. The snails were regularly supplied with lettuce leaves, as food. The

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snails started egg-laying within a few days. The egg capsules were collected on a daily basis from the aquarium, and kept inside a glass jar (1000 ml capacity) containing pond water. In one glass jar 7-10 egg capsules deposited within a 24 hr period, were kept together. The water in the glass jars was changed regularly with fresh pond water. Through regular observation newly hatched (zero-day-old) snails were taken daily from the jars. The required number of individuals, when available, were studied. These newly hatched snails were placed in a plastic container (2 l capacity) containing pond water. The containers were kept at 10°, 15°, 20°, 25°, 30° and 35°C ($\pm 1^\circ\text{C}$) temperatures (maintained in Biological Oxygen Demand Chamber), and at room temperature (19.6°-29.6°C) in order to study the effect of these temperatures on the *L. (R.) luteola*. The experiments were conducted (i) using five different types of food viz. lettuce (*Lactuca sativa*), mustard (*Brassica nigra*), radish (*Raphanus sativus*), spinach (*Spinacea oleracea*) and aquatic weeds (*Chara, Vallisneria*), (ii) by maintaining three different levels of pH, viz. 5, 7 and 9 in the culture water and (iii) by maintaining three different grades of salinity viz 0.5, 1.5 and 2.5 NaCl ‰. The snails under experimental study with different pH and salinity grades were fed lettuce. The water in the containers was changed regularly at an interval of 12 hr in order to maintain the pH and salinity at desired levels. The pH was maintained by adding HCl and NaOH, and the salinity was maintained by adding HCl to the freshly collected pond water at an interval of 12 hr. A few examples of *Ipomoea* were kept in each container to provide resting and egg-laying sites for the snails. Dead snails' faecal pellets and unconsumed food materials were removed every 12 hr, at the time of removal of water in each container.

Data on the life-cycle parameters viz. the growth rates, the age of attainment of sexual maturity, the duration of reproductive period, the rate of egg production, the death rate and the life span of the snails was collected regularly. In the course of data collection, attention was paid to record the time taken by the eggs to hatch and the hatchability percentage of the eggs, exposed to different temperatures. Measurements of growth in shell length, shell width and total body weight were taken every two weeks, from ten individuals, selected at random, from the total population. But, when the number was ten or less, all were considered for data collection. In the case of the study of egg-laying potential, the total number of egg capsules produced by the snails in the container were recorded daily. The number of eggs present in these

capsules was also counted and recorded. In all cases the average was calculated for presentation of final data in respect to the life-cycle parameters considered for study. One-way ANOVA was applied for statistical interpretations of the data. Detailed comparisons of the data by way of ANOVA studies were made following Campbell (1989).

RESULTS

L. (R.) luteola had different life spans (5.43 - 64.82 days) when cultured at different temperatures in respect to the type of food they consumed (Fig. 1) and the pH and salinity of the maintenance water (Fig. 2). They exhibited marked variation in the rates of growth, in shell length, shell breadth and body weight when reared at different temperatures (Fig. 3). In general, body weight increased with the increase of temperature from 10° to 35°C, at intervals of 5°C. But the snails attained maximum body weight per day when maintained at room temperatures. Though a similar trend in the growth rates in shell length and shell width is noted in snails maintained from 10° to 30°C, slight variations in the rate of increase were seen in individuals exposed to 35°C and room temperatures. The snails cultured at 35°C with mustard leaves attained maximum shell size (16 mm in shell length and 10 mm in shell width). In contrast to this the lettuce fed individuals exposed to 30°C at 0.5 NaCl ‰ attained maximum body weight (4.20 mg) having 15 mm shell length and 9 mm shell width.

Among the snails exposed to 10°C and 15°C, irrespective of the type of food, pH and salinity of water, and those cultured at pH 5 and 9, irrespective of temperatures, died prior to attaining sexual maturity (Figs 1, 2). The snails in the remaining cultures became sexually mature between 25 and 93 days after hatching and the percentages of such snails varied from 6.70 to 70.00 (Figs 1, 2). Individuals maintained at 1.5 NaCl ‰ under room conditions with lettuce as food, reproduced on an average, only for a period of 8 days, while those reared at 20°C with radish leaves as food reproduced for a period of 61.50 days (Figs 1, 2). The rate of egg production varied with the snails in respect to the cultures maintained (Figs 1, 2). At room temperature, a lettuce fed snail on an average deposited 0.27 eggs per day but the number was as high as 18.35 in case of lettuce fed snails cultured with 2.5 NaCl ‰ at 30°C. The eggs deposited by the snails of different culture stocks required, on an average, 7.0 to 10.50 days to hatch out (Figs 1, 2). The percentage of hatching was highest (96.20%) in eggs deposited by lettuce fed snails kept at room temperature and lowest

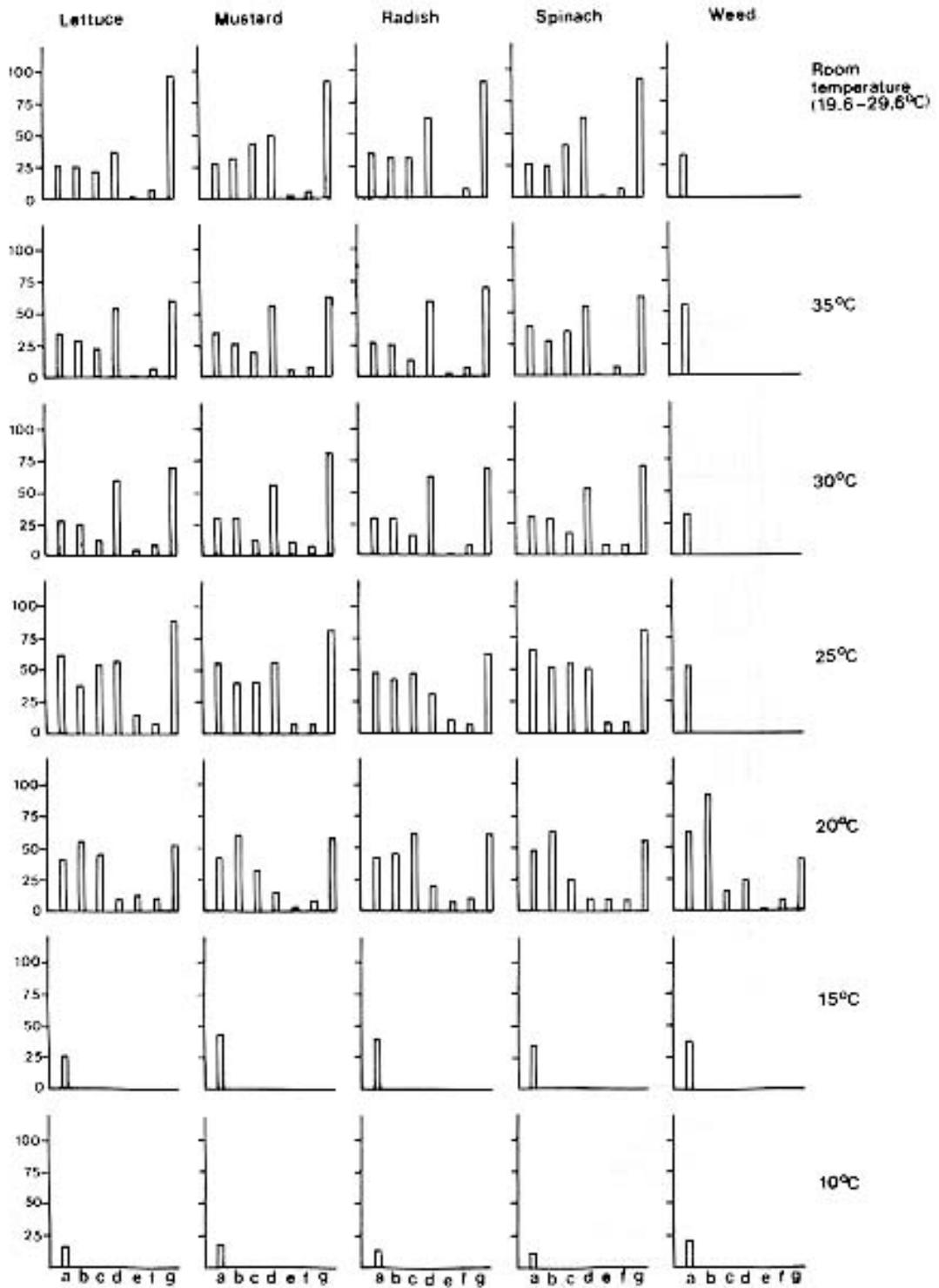


Fig. 1: influence of temperature on the life cycle parameters [a: longevity (in days), b: age of attainment of sexual maturity (in days), c: length of reproduction period (in days), d: snails attained sexual maturity (in per cent), e: rate of egg production (in number), f: developmental period of egg (in days), g: hatchability of egg (in per cent)] of *Lymnaea (Radix) luteola* maintained with five different types of food.

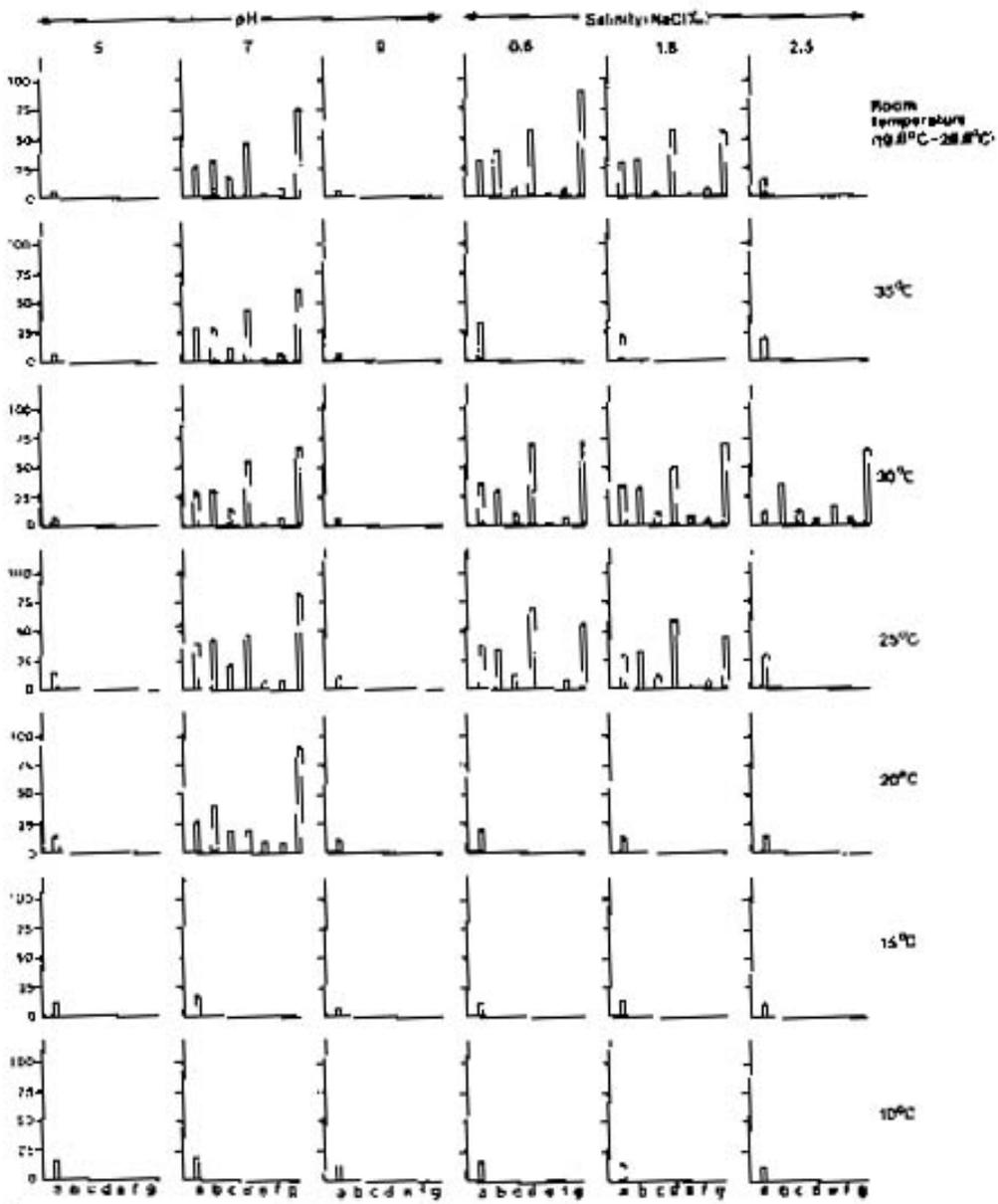


Fig. 2: influence of temperature on life cycle parameters of *Lymnaea luteola*.

Fig. 2: influence of temperature on the life cycle parameters [a: longevity (in days), b: age of attainment of sexual maturity (in days), c: length of reproduction period (in days), d: snails attained sexual maturity (in percent), e: rate of egg production (in number), f: developmental period of egg (in days), g: hatchability of egg (in per cent)] of *Lymnaea (Radix) luteola* maintained at different pH and salinity with the supply of lettuce food.

(43.70%) in eggs produced by weed fed snails exposed to 20°C (Figs 1, 2). Marked variations have been noted in mortality rates of the snails exposed to different temperatures. The average daily death rate ranged from 0.28% to 2.72% (Table I). The snails exhibited the lowest growth rate at 10°C. An increasing rate of growth is evident with the rise of temperature. Detailed comparisons on the

effect of all other higher temperatures in respect to 10°C were made by applying ANOVA, to determine the optimum temperature for growth, reproduction and development. From the F values (Table II-IV) it is evident that temperature has significant effect on these events in *L. (R.) luteola* in respect to the type of foods used and the pH and salinity grades maintained.

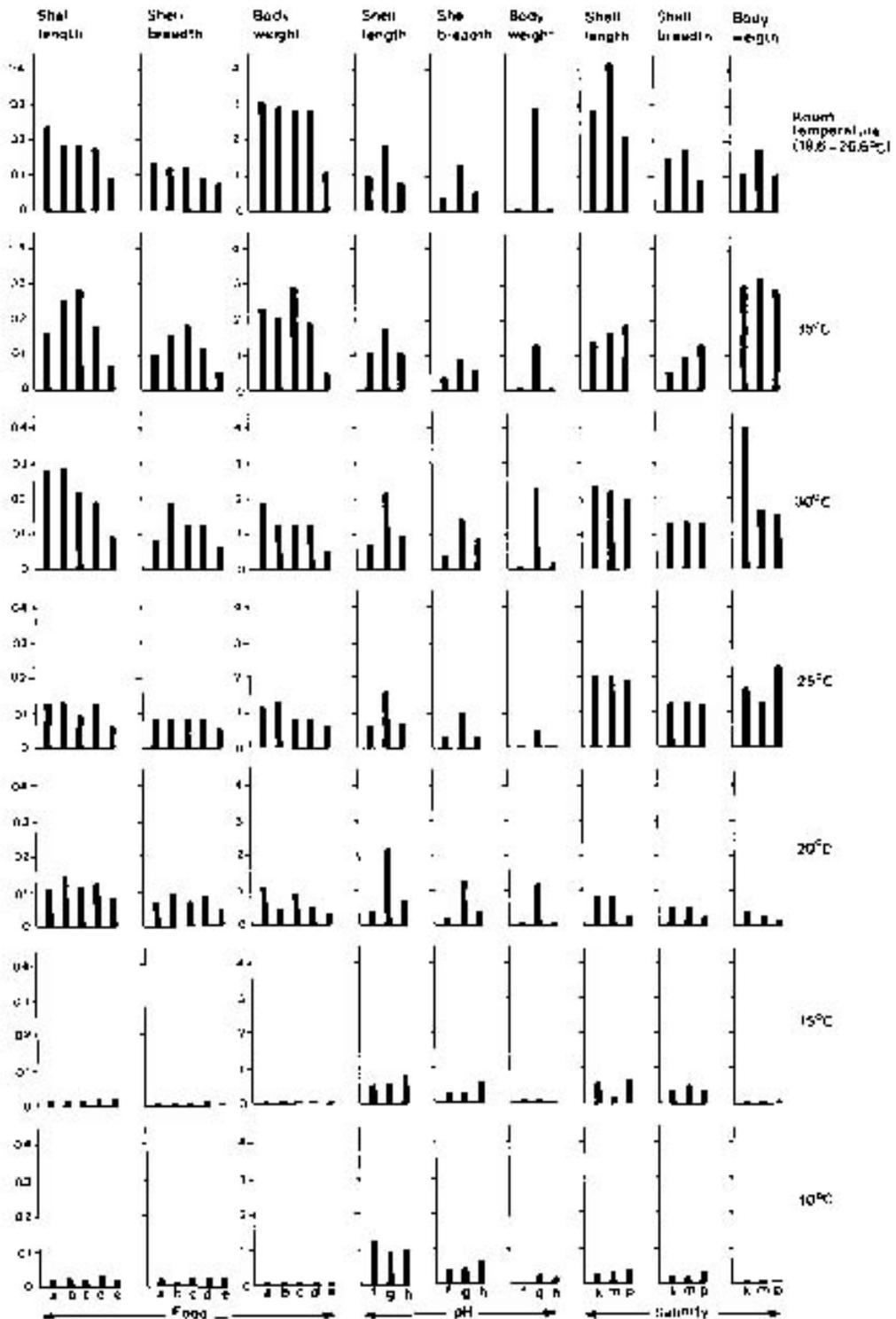


Fig. 3: influence of temperature on the daily rates of growth in shell length (mm), shell breadth (mm) and body weight (mg) of *Lymnaea (Radix) luteola* maintained with different foods (a: lettuce, b: mustard, c: radish, d: spinach, e: weed), pH (f: 5, g: 7, h: 9) and salinity (k: 0.5 NaCl ‰, m: 1.5 NaCl ‰, p: 2.5 NaCl ‰).

TABLE I
Influence of temperature on the death rates (avarege % per day) of *Lymnaea (Radix) luteola*

Temperature (°C)	Food					pH			Salinity (NaCl‰)		
	Lettuce	Mustard	Radish	Spinch	Weed	5	7	9	0.5	1.5	2.5
10	1.00	0.61	1.33	1.42	0.64	1.00	0.68	1.20	0.88	0.96	1.30
15	0.63	0.56	0.51	0.57	0.60	1.07	0.75	1.15	0.71	0.96	1.07
20	0.33	0.36	0.33	0.38	0.33	1.07	0.49	1.36	0.56	0.65	0.76
25	0.34	0.38	0.33	0.33	0.28	1.20	0.35	1.57	0.68	0.71	0.85
30	0.68	0.60	0.50	0.42	0.45	2.00	0.50	2.72	0.51	0.48	0.46
35	0.62	0.71	0.85	0.54	0.32	2.14	0.50	2.14	0.32	0.35	0.40
Room	0.60	0.55	0.75	0.45	0.39	2.14	0.52	2.50	0.76	0.83	1.16

DISCUSSION

Temperature is considered as a critical environmental factor in the ecology of most organisms (Precht et al. 1973, Magnuson et al. 1979, Vianey-Liaud 1982, Ahmed & Raut 1991, Raut et al. 1992). It can act as both a trigger for the commencement of a biological process and as a threshold essential for its continuation. The results of the present study are in agreement with the comment of previous workers so far as the influence of temperature on the biology of *L. (R.) luteola* is concerned. It is evident that *L. (R.) luteola* is unable to complete its life-cycle at 10° and 15°C temperatures, irrespective of the foods it consumes, and the pH and salinity grades maintained. Also, it fails to attain sexual maturity at 25°C, 30°C, 35°C and room temperatures when fed weed, at all the temperature gradients when maintained with lettuce at pH 5 and 9, and at 20° and 35°C in all the three salinity grades, and at 25°C and room temperatures when the snails were exposed to 2.5 NaCl ‰ with the supply of lettuce food. In these experiments the snails exhibited marked variations in the rates of growth in shell length, shell breadth and body weight. In all other experiments the snails were able to complete their life-cycle although significant variations in the rates of growth, multiplication and survival have been noted in respect to the temperatures of the waters of the containers concerned. Also, in most cases the effects of temperature on the life-cycle parameters of *L. (R.) luteola* are influenced by the factors like quality of food, pH, and salinity of water used in experiments. Detailed comparisons in respect to 10°C revealed that the effect of 15° and 20°C is significant while at 25°, 30°, 35°C and room temperature the same is significant either at 5% or 1% or 0.1% level when the snails were cultured in waters having three different salinity grades but fed with lettuce.

The overall effect of temperatures (20°, 25°,

30°, 35°C and room temperatures) irrespective of foods is significant at 0.1 % level. From the F values, it appears that the degree of interaction is almost at the same level as far as the results of 35°C and room temperatures are concerned. Though the effect of temperature on the age of attainment of sexual maturity in snails is significant at 0.1% level throughout, the degree of interaction is gradually higher with the rise of temperature from 20° to 35°C and the impact of room temperature lies in between 30° and 35°C. In contrast to this, the effect of 30°C is highly significant as far as the duration of reproduction of a snail individual is concerned. However, room temperature has its biggest effect on the rate of egg production, the time required for the development of embryo and the hatchability of eggs. It seems that even under all other similar factors, temperature plays a significant role to regulate the physiology of the snails. As the physiological status of an organism depends greatly on the available food, it is obvious that the life-cycle parameters of snails would vary accordingly. This is dependent on the rate of feeding and conversion of carbohydrate, protein and fat from plant food sources, to snails' body, at various temperatures, as has been discussed by Ahmed and Raut (1991). Since anomalies in longevity in snails cultured at different pH and salinity of water are well marked at identical temperatures with identical food supply (lettuce) it is assumed that, at least pH and salinity (since other factors have not been considered in the present study) play important roles in the life process. This is why the snails cultured at pH 5 and 9 in all the temperatures and those cultured in 0.5, 1.5 and 2.5 NaCl ‰ at 20° and 35°C, in 2.5 NaCl ‰ at 25°C and room temperature failed to attain sexual maturity. Since the percentage of sexually mature snails varied with the thermal conditions of the water used in cultures, it is apparent that adaptability in snails varied with the individuals.

TABLE II

Calculated F-values in respect to the effect of temperature on the rates of growth in shell length, shell breadth and body weight of *Lymnaea (Radix) luteola* cultured with different food, pH and salinity. The snails considered for experiments with pH and salinity grades were fed with lettuce

		Overall temperature (°C)	F - values					
			10°C v 15°C	10°C v 20°C	10°C v 25°C	10°C v 30°C	10°C v 35°C	10°C v RT ^a
FOOD								
Lettuce	SL	232.9599 ^d	0.54048 ^{NS}	14.008 ^d	83.838 ^d	519.40841 ^d	448.8681 ^d	323.2248 ^d
	SB	106.061 ^d	0.36395 ^{NS}	12.56198 ^d	54.61535 ^d	220.69628 ^d	234.34443 ^d	170.19813 ^d
	BW	23.87437 ^d	0.0000017 ^{NS}	0.092188 ^{NS}	6.76323 ^b	14.83858 ^d	27.27309 ^d	65.95603 ^d
Mustard	SL	99.8607 ^d	0.63236 ^{NS}	7.29835 ^c	69.62724 ^d	82.9343 ^d	311.42371 ^d	178.94451 ^d
	SB	115.5086 ^d	1.6284 ^{NS}	12.3147 ^d	84.9382 ^d	109.3454 ^d	385.6348 ^d	194.0626 ^d
	BW	20.069 ^d	0.0015 ^{NS}	0.08148 ^d	10.14991 ^c	8.73583 ^c	20.9362 ^d	63.8118 ^d
Radish	SL	84.4485 ^d	0.29211 ^{NS}	5.79649 ^b	19.12287 ^d	26.61654 ^d	126.6030 ^d	75.63445 ^d
	SB	70.5185 ^d	0.17554 ^{NS}	4.99317 ^b	14.21884 ^d	21.24049 ^d	112.65847 ^d	50.73142 ^d
	BW	20.0286 ^d	0.00057 ^{NS}	0.06106 ^{NS}	1.25135 ^{NS}	3.58918 ^{NS}	13.30939 ^d	24.3467 ^d
Spinach	SL	196.288 ^d	2.37716 ^{NS}	7.37351 ^c	17.92859 ^d	296.28782 ^d	255.05248 ^d	163.70434 ^d
	SB	115.0946 ^d	1.6534 ^{NS}	0.3036 ^{NS}	1.2147 ^{NS}	117.4598 ^d	117.4598 ^d	65.3266 ^d
	BW	19.6597 ^d	0.0071 ^{NS}	0.03679 ^{NS}	0.2517 ^{NS}	5.7244 ^b	13.19195 ^d	32.9967 ^d
Weeds	SL	43.6548 ^d	0.06316 ^{NS}	7.6427 ^c	98.5504 ^d	11.51149 ^d	88.8232 ^d	114.0885 ^d
	SB	29.7185 ^d	0.0253 ^{NS}	6.4772 ^b	58.2948 ^d	2.5301 ^{NS}	58.2948 ^d	79.3458 ^d
	BW	13.0963 ^d	0.0095 ^{NS}	0.5217 ^{NS}	29.2403 ^d	10.1250 ^c	21.0454 ^d	34.9871 ^d
pH								
7	SL	58.4309 ^d	1.1685 ^{NS}	9.1678 ^c	6.1193 ^b	13.8420 ^d	191.3543 ^d	75.8209 ^d
	SB	41.2814 ^d	1.3529 ^{NS}	8.4981 ^c	4.7515 ^b	13.3263 ^d	142.165 ^d	43.4538 ^d
	BW	17.1293 ^d	0.0236 ^{NS}	9.5800 ^c	3.6585 ^{NS}	14.7600 ^d	12.5923 ^d	54.2077 ^d
SALINITY								
0.5	SL	64.6700 ^d	0.52054 ^{NS}	1.25166 ^{NS}	77.52049 ^d	131.00964 ^d	128.2756 ^d	52.47208 ^d
	SB	54.2044 ^d	0.00	0.81813 ^{NS}	55.38133 ^d	101.76491 ^d	1085474 ^d	39.4916 ^d
	BW	30.3721 ^d	0.001892 ^{NS}	0.092266 ^{NS}	12.02545 ^c	59.01068 ^d	40.55779 ^d	3.77305 ^{NS}
1.5	SL	34.1543 ^d	0.00	0.8889 ^{NS}	46.1463 ^d	61.2116 ^d	71.9048 ^d	38.8243 ^d
	SB	47.0703 ^d	0.10986 ^{NS}	1.31833 ^{NS}	58.0140 ^d	100.2592 ^d	90.2399 ^d	60.6506 ^d
	BW	24.68056 ^d	0.000143 ^{NS}	0.068992 ^{NS}	18.040039 ^d	41.183069 ^d	31.09833 ^d	10.29576 ^c
2.5	SL	60.5464 ^d	1.19731 ^{NS}	1.04765 ^{NS}	36.04426 ^d	54.5528 ^d	128.9706 ^d	70.6467 ^d
	SB	79.3267 ^d	0.89605 ^{NS}	1.6001 ^{NS}	45.17622 ^d	64.7401 ^d	170.8553 ^d	97.9838 ^d
	BW	26.7642 ^d	0.00262 ^{NS}	0.07325 ^{NS}	2.23176 ^{NS}	12.00418 ^c	55.82649 ^d	6.96791 ^b

SL: shell length, SB: shell breadth, BW: body weight a: Room temperature (19.6°C - 29.6°C) b, c, d: significant at 5, 1 and 0.1% levels, respectively NS: not significant

TABLE III

Calculated F-values in respect to the effect of temperature on the longevity and mortality of *Lymnaea (Radix) luteola* maintained with different foods, pH and salinity

		Over all temperature (°C)	F - values					
			10°C v 15°C	10°C v 20°C	10°C v 25°C	10°C v 30°C	10°C v 35°C	10°C v RT ^a
Longevity	Food	194.2927 ^d	20.2881 ^d	48.6286 ^d	87.3681 ^d	9.0907 ^d	25.0906 ^d	9.9420 ^d
	pH	0.23739 ^{NS}	-	-	-	-	-	-
	Salinity	4.05357 ^c	0.12208 ^{NS}	0.0931 ^{NS}	11.2378 ^d	6.0556 ^c	3.9789 ^b	4.88203 ^c
Mortality	Food	7.48837 ^d	14.6540 ^d	34.5377 ^d	36.0323 ^d	8.1424 ^d	12.4082 ^d	6.4974 ^d
	pH	0.7373 ^{NS}	-	-	-	-	-	-
	Salinity	4.5821 ^c	0.7771 ^{NS}	6.6492 ^c	3.9344 ^b	13.8731 ^d	20.8134 ^d	0.7388 ^{NS}

a: room temperature (19.6°C - 29.6°C) b, c, d: significant at 5, 1 and 0.1% levels, respectively
 NS: not significant - : did not compare due to overall insignificant effect

TABLE IV

Calculated F-values in respect to the effect of temperature on the life cycle parameters of *Lymnaea (Radix) luteola*

Life cycle parameters	Overall temperature (°C)	F - values			
		20°C v 25°C	20°C v 30°C	20°C v 35°C	20°C v RT ^a
Age of attainment of sexual maturity	11.9278 ^d	10.9894 ^d	29.9788 ^d	31.7239 ^d	27.4537 ^d
Percentage of snails attained sexual maturity	21.40902 ^d	34.7113 ^d	58.4479 ^d	54.4861 ^d	46.3688 ^d
Length of reproduction period	5.81155 ^c	3.2484 ^b	8.4108 ^d	3.0781 ^b	0.1123 ^{NS}
Rate of egg production	5.11786 ^c	4.6144 ^c	0.0234 ^{NS}	2.1071 ^{NS}	5.2031 ^c
Developmental period of eggs	28.0615 ^d	21.8266 ^d	18.2256 ^d	75.6797 ^d	82.8493 ^d
Hatchability percentage of eggs	21.4329 ^d	28.4455 ^d	17.2704 ^d	6.2343 ^c	78.4124 ^d

a: room temperature (19.6°C - 29.6°C) b, c, d: significant at 5,1 and 0.1% levels, respectively NS: not significant

Such adaptability of the snails has been reflected in the length of the reproduction period and the rates of egg production. This phenomenon is also well evident from the facts of variations in the length of the reproduction period and in the rates of egg production in snails exposed to 1.5 and 2.5 NaCl %. Similar effects of temperature on the rate of growth, reproduction, and behaviour have been noted in *Lymnaea stagnalis* by Vaughn (1953), in *Australorbis glabratus* by Michelson (1961), in *Bulinus (Physopsis) globosus* by Shiff (1964), in *Biomphalaria pfeifferi* by Sturrock (1966) and Appleton (1977), in *Biomphalaria glabrata* by Chernin (1967), Sturrock and Sturrock (1972) and Vianey-Liaud (1982), in *Biomphalaria pfeifferi* by Shiff and Garnett (1967), in *Bulinus truncatus* and *Biomphalaria alexandrina* by El-Hassan (1974) and in *Indoplanorbis exustus* by Raut et al. (1992).

The rate of population growth of a species is very much governed by the length of the incubation period and hatchability of its eggs (if the species is oviparous). Marked variations in the length

of the incubation period of the eggs and the percentage of hatching of eggs in respect to temperature have been noted in *Lymnaea luteola*, *L. acuminata*, *I. exustus* and *Gyraulus convexiusculus* (Saha & Raut 1992). The present findings are in agreement with earlier observations although variations in hatching percentages of the eggs produced by the snails, reared at the same temperature, but fed with different foods, are recorded for the first time. This may be explained by the relationship of stored nutrients in the eggs, to the type of foods consumed by the mother snails concerned. As hatching success of the eggs varied with the pH and salinity grades it is obvious that these factors have significant influence to alter the beneficial effects of temperature, to a certain extent. The present observations provide a sound basis for understanding the findings of Chitramvong et al. (1981) on *Bithynia siamensis siamensis*, *Radix rubiginosa* and *Indoplanorbis exustus* and of Raut and Misra (1991, 1993) on *L. (R.) luteola*, *I. exustus* and *Gyraulus convexius-*

culus .

From the foregoing accounts it appears that the potential of an organism is very much dependent on its ability to adjust to the factors to which it is exposed. Further, it may be stated that the power of adjustment of an organism is determined by its 'genome' (Boughey 1973) or 'dynamic' (Misra & Raut 1993) factor. Depending upon these factors, the trend of population growth rate in a species as well as the probability of variations in 'strain' are determined. Such studies, from different parts of the globe, although numerous (Newton 1955, Paraense 1955, Richards 1973, Scherrer et al. 1976, Vianey-Liaud 1989, Misra & Raut 1993), are lacking information on the cumulative effect of different ecological parameters in respect to the strains of the snail species.

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