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Effect of leaf ration on dietary water budget of the larvae of silkworm *Bombyx mori* and eri silkworm *Philosamia ricini*

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Abstract. Dietary water intake in penultimate two instars of silkworm *Bombyx mori* and eri silkworm *Philosamia ricini* fed *ad libitum* on mulberry leaf *Morus alba* and castor leaf *Ricinus communis* respectively at 26±2°C is reported. The lower ration level results in accumulation of water content in the body of insects. The water retention efficiency (per cent of absorbed water retained in the body) increases with the decreasing ration level. The larva retains higher amount of water in the body by increasing water retention efficiency from 22% at 100% ration to 61% at 25% ration. This is an important adaptive mechanism exhibited by larvae. The water utilization budgets are discussed with the budgets available for other insects.

Keywords. Dietary water; water retention efficiency; *Bombyx mori*; *Philosamia ricini*.

1. Introduction

The importance of water in relation to food intake and utilization has been stressed by many authors (Michael *et al* 1971; Reese and Beck 1978; Scriber and Slansky 1981; Delvi 1983; Reddy 1981). Water is a very important component of insect diet (Ross 1956) particularly in the leaf feeders like the *Bombyx mori* and *Philosamia ricini*, which meet their water requirement from their food (Delvi and Naik 1984).

There are few reports concerning the dietary water balance and the effects of environmental factors like temperature, leaf ration (Pandian *et al* 1978; Delvi 1983) and insecticides (Naik and Delvi 1984). The water gain and loss during ingestion and digestion of food and mechanisms regulating them have not been studied adequately in economically important insects of *B. mori* and *P. ricini*. This communication reports on the effect of ration levels on water budget of penultimate two instars of *B. mori* and *P. ricini*.

2. Material and methods

Egg layings of *B. mori* (pure Mysore race) were obtained from the grainage of the Government of Karnataka (Magadi area) and eggs of *P. ricini* were obtained from University of Agricultural Sciences, GKVK Campus, Bangalore and maintained in the laboratory. Freshly hatched larvae were removed to separate terraria (plastic trays size 36 × 26 × 4 cm). The larvae were maintained in the laboratory fed on leaves of *Morus alba* and *Ricinus communis* respectively at room temperature and humidity which averaged 26±2°C; 80±10% RH. Lepidopteran larvae consumed more than 97–98% of the total food intake during the final two instars (Waldbauer 1968). Hence, the effect of ration level on water consumption and utilization was estimated in the penultimate two instars in *B. mori* and *P. ricini*. The test individuals were reared in 3 groups (each consisting of 50 larvae) and experiments were triplicated in each group. The larvae were fed on fresh leaves of *M. alba* and *R. communis* at 100, 75, 50 and 25% ration levels. The ration levels were fixed considering the food consumption values of *B. mori* and *P. ricini* fed *ad libitum* separately (see also Naik 1986).

Fresh leaves of *M. alba* and *R. communis* were cut into two halves, one half was weighed and offered to larvae and the other was used as control to find the initial water content (Delvi and Pandian 1972). Larvae began to feed as soon as the leaf was offered. Since they fed throughout the day, the fresh leaves were offered 4 times a day to minimise the amount of water evaporated from the leaves. Amount of daily food intake was calculated following the standard gravimetric method described by Waldbauer (1968), Delvi (1983), Naik and Delvi (1984) and Delvi and Naik (1984).

Some insects are known to obtain atmospheric water through the integument (Bodine 1921; Lugwig 1937; Beament 1964) and in few cases via cloacal ends (Beament 1961) or via the spiracles (Buxten 1932). *B. mori* and *P. ricini* should have exchanged a considerable amount of water with ambient air; however, this was not estimated (see also Uvarov 1966; Delvi 1983). The absorption of atmospheric water and transpiration of body water through integument have been dealt in detail by previous workers (Wigglesworth 1957; Edney 1957, 1967; Ebeling 1964; Cloudsley-Thompson 1962; Beament 1964). Perhaps *B. mori* and *P. ricini* meets almost complete required water from the ingested leaf of *M. alba* and *R. communis* (see also Pandian *et al* 1978; Delvi 1983).

3. Results

The initial water content of the larvae chosen for the experiments changed little and averaged $77{\cdot}5 \pm 0{\cdot}2\%$ in *B. mori* and $82 \pm 1{\cdot}2\%$ in *P. ricini* immediately after the completion of third instar (table 1). At pupation water content of the terminal *B. mori* larvae decreased to 67% during 100 and 75% feeding. However, the decreased ration level resulted in increased water content of 86·5 at 50% ration level and 90% at 25% ration level in *B. mori*. Such differences in the final water content of the larvae are not found in *P. ricini*, where the water content change little with different ration levels and averaged about 78%. Perhaps less percentage of water found in the fifth instar larvae of *B. mori* during 100 and 75% ration levels may be due to the fact that

Table 1. Effect of ration feeding on the water content of the larvae and excreta in *B. mori* and *P. ricini*.

Ration (% of *ad libitum* = 100%)	*B. mori*					*P. ricini*				
	Water content of the larvae			Water content of the excreta		Water content of the larvae			Water content of the excreta	
	IV Instar	V Instar	Final day	IV Instar	V Instar	IV Instar	V Instar	Final day	IV Instar	V Instar
100	74·4	84·34	66·8	34·42	34·42	81·5	79·9	78·5	22·9	37·3
75	77·5	82·54	67·0	34·42	34·42	82·8	81·3	77·4	16·9	28·9
50	77·6	87·8	86·5	19·2	39·4	82·3	78·6	77·8	14·7	25·6
25	77·5	88·9	89·9	16·7	38·6	81·3	79·9	78·2	19·3	31·9

excess amount of water was lost through the faeces during the fifth instar period.

The water content of freshly defaecated pellets in *B. mori* reduced initially in the fourth instar larvae depending on the ration level; the 100 and 75% feeding exhibited no significant difference in the water content of excreta and averaged 34·4%. A change in the ration level to 50% reduced the water content of excreta to 19·2% and further to 16·7% at 25% ration level. However, during fifth instar, the water content of the faeces range from 34·4–39·4% in all the groups of *B. mori*. In *P. ricini* a similar trend of water content of the excreta is found.

With the decreasing ration level, the amount of water retained in the body by the test individuals decreased. The larvae of *B. mori* consumed 5603 mg of water at 100% ration level; of this 85·4% was absorbed and 14·6% lost with faeces. A part of the absorbed water is retained in the body which amount to 1012 mg which is about 21·8% of the absorbed water. This water retention efficiency (per cent of absorbed water retained in the body) increases with the decreasing ration level. The efficiency was 27·6% with 75% ration, 44% with 50% ration and 61% with 25% ration (table 2). The decreasing ration level reduces the amount of water available to each insect. The water input is uniformly absorbed with the maximum efficiency of about 85% at all the tested ration levels. However, *B. mori* larva retained higher amount of water in the body by increasing water retention efficiency from about 22% at 100% ration to 61% at 25% ration. This is an important adaptive potential exhibited by the larvae. Similarly *P. ricini* larvae also increased the water retention efficiency with the decreasing ration levels. *P. ricini* absorbs the water with an efficiency ranging from

Table 2. Effect of ration levels on water utilization in final two instars of *B. mori* at 26 ± 2°C; 80 ± 10% fed *ad libitum* mulberry leaf *M. alba*.

	Ration			
Parameters	100%	75%	50%	25%
Larval period (day)	16·00	19·00	18·00	19·00
Dietary water intake (mg/insect)	5602·75	4453·60	3559·81	2133·10
Water loss through faeces (mg/insect)	971·56	879·10	645·68	377·36
Water absorbed (mg/insect)	4631·14	3574·50	2914·13	1755·74
Water retained in the body (mg/insect)	1011·80	985·42	1281·90	1070·70
Water loss through transpiration (mg/insect)	3619·34	2589·08	1632·22	685·04
Water intake rate (mg/mg/day)	0·607362	0·399158	0·348643	0·221054
Water loss rate through faeces (mg/mg/day)	0·081589	0·065795	0·036926	0·025188
Water absorption rate (mg/mg/day)	0·525973	0·258472	0·311718	0·195867
Water transpiration rate (mg/mg/day)	0·410061	0·243669	0·196385	0·0489711
Water absorption efficiency (%)	85·36	82·90	87·28	87·05
Water retention efficiency (%)	21·80	27·60	44·00	61·00

89–94% at different ration levels. The water retention efficiency increases from 32·5% at 100% ration level to 44·5% at 25% ration level (table 3).

Though the food offered was regulated at different ration levels after knowing the amount of food consumed fed *ad libitum*, the water intake was found to increase from 4–13% in *B. mori* and from 4–20% in *P. ricini* at different ration levels. This may be due tc the increase in larval period at the decreased ration levels (tables 2 and 3). The water intake rate fluctuates widely in larvae receiving different rations (tables 2 and 3). The rate is higher during the fourth instar than the fifth at all the ration levels. Individuals of *B. mori* offered 100% ration display a higher water intake rate of 0·607362 mg/mg live weight of insect/day. Although the to:al water intake rate of individuals with 100 and 75% rations is higher than those fed with 50 and 25% rations, the latter fed actively while the former fed slowly at different intervals.

Both *B. mori* and *P. ricini* exhibited decreased rate of water loss through faeces with the increasing ration levels. The transpiration rate decreases steadily with decrease in the ration level. However the efficiency of water absorption changed little in both the test insects and averaged 85·6% in *B. mori* and 91·6% in *P. ricini*.

4. Discussion

Ingestion of water via food and subsequent absorption of water decreases with the decrease in ration levels in both *B. mori* and *P. ricini*. Dietary water intake or water absorbed steadily decreased from a maximum 5602·7 or 4631·1 mg at 100% ration to

Table 3. Effect of ration levels on water utilization in the final two instars of *P. ricini* at 26 ± 2°C; 80 ± 10% fed *ad libitum R. communicus*.

	Ration			
Parameters	100%	75%	50%	25%
Larval period (day)	7·00	9·00	9·50	11·00
Dietary water intake (mg/insect)	13181·30	10537·35	9230·81	5761·95
Water loss through faeces (mg/insect)	1979·58	1130·194	732·98	650·779
Water absorbed (mg/insect)	11200·98	9407·17	8497·92	5111·18
Water retained in the body (mg/insect)	3649·01	3274·83	2694·32	2273·26
Water loss through transpiration (mg/insect)	7551·06	6132·35	5803·54	2837·92
Water intake rate (mg/mg/day)	0·898819	0·74023	0·785319	0·516784
Water loss rate through faeces (mg/mg/day)	0·073486	0·052142	0·044872	0·0412611
Water absorption rate (mg/mg/day)	0·825318	0·68809	0·73786	0·4778403
Water transpiration rate (mg/mg/day)	0·524684	0·424189	0·502289	0·293431
Water absorption efficiency (%)	89·23	92·21	93·95	92·07
Water retention efficiency (%)	32·58	34·81	31·71	44·48

2133·1 or 1755·7 mg at 25% ration in *B. mori*. In *P. ricini* the decrease in the water intake or absorption ranges from 13181·3 or 11200·98 mg at 100% ration to 5761·9 or 5111·2 mg at 25% ration. The reduced ration levels (75, 50 and 25%) resulted in reduction in intake and utilization of water in both the test insects. The qualitative and quantitative importance of water with negative effects has been observed by several workers (Delvi and Naik 1984; Naik and Delvi 1984; Radhakrishna and Delvi 1987). A survey of relevant literature reveals the paucity of information regarding the effects of ration levels on water utilization. Though there are several papers on effects of other environmental factors like temperature (Delvi 1983; Pandian *et al* 1978), insecticides (Delvi and Naik 1984; Naik and Delvi 1984), the only paper that is available on the effect of leaf ration on the water budget is that of Pandian *et al* (1978). Delvi (1983) and Pandian *et al* (1978) have given valuable data on the water utilization of a lepidopteran insect *Danaus chrysippus*. In *D. chrysippus* with increasing ration, there was considerable increase in the dietary water intake, absorption and retention (Pandian *et al* 1978). In *B. mori* and in *P. ricini* the increasing ration level resulted in increased dietary water intake and utilization; the larvae fed 100 and 75% ration ingested and absorbed more water than the group receiving 50 and 25% ration. It has been demonstrated that *D. chrysippus* economises the water loss through reduced transpiration at lower rationing (Pandian *et al* 1978). It can be seen from tables 2 and 3 that ration levels had no influence on water absorption efficiency in both *B. mori* and *P. ricini* which retained around 85–90%. However, the water retention efficiency increases with the decreasing ration level; from 18% at 100% ration to 50% with 25% ration in *B. mori* and from 32·5% at 100% ration to 44·5% at 25% ration in *P. ricini*. This observation suggests that the lepidopteran larvae manage to get more water either by increasing the efficiency of water absorption (Pandian *et al* 1978; Delvi 1983) or by increasing the water retention efficiency (present work) during any unfavourable conditions. The conclusion is significant in the light of understanding the adaptive potential of the terrestrial insects.

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