

## Effects of insecticide, permethrin, on dietary water utilization in eri-silkworm *Philosamia ricini*

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**Abstract.** Dietary water intake in Eri-silkworm *Philosamia ricini* fed *ad libitum* castor leaf *Ricinus communis* from hatching to pupation at  $26 \pm 2^\circ\text{C}$  averaged 16174 mg/insect. As much as 3966 mg of dietary water is lost *via* faeces and 65% of the absorbed water is lost through transpiration retaining only 35% in the body. Rates of water intake, absorption, loss *via* faeces and transpiration decrease from the 1st instar to Vth instar larvae and are correlated to the increasing body weight and/or age. Water intake in *P. ricini* fed permethrin, a pyrethroid insecticide, treated leaf *R. communis* averaged 8649 mg/insect which is about 50% less than the normal intake. Water utilization in the insecticide fed *P. ricini* is considerably less than the normal. It is suggested, the mechanism by which insecticide inhibit the utilization of water could be through, repellency, disruption of feeding physiology and other chronic toxicity possibly related to insecticide action.

**Keywords.** Dietary water; *Philosamia ricini*; *Ricinus communis*; transpiration

### 1. Introduction

In insects, as in other organisms, water is the fundamental basis of metabolic processes since practically all the processes occur in aqueous solution. Hence, water is a very important item of insect diet. Most of them obtain water from foodstuffs with fairly high water content, such as foliage and blood (Ross 1956). Recent studies (Pandian *et al* 1978; Delvi 1983) have shown that food consumption by insects supplemented with water utilization is required to know the important clues with regard to the success of terrestrial insects. Environmental factors like temperature and food quality play an important role in understanding the interaction between an insect and its surroundings (Delvi 1983). Recent workers have measured the effects of external factors like temperature, leaf ration etc., on water utilization of Orthoptera (Delvi 1983) and Lepidoptera (Pandian *et al* 1978). Moore (1967) stressed the importance of pesticides in ecological research. Toxicological studies at the organism level are mostly confined to the assessment of lethality, fecundity and retardation of growth and development of economically important insects like *Bombyx mori* L (Tsujiita 1950; Watanabe and Takano 1966; Kuwana *et al* 1967, 1968; Kashi 1972; Kuribayashi 1982; Ross and Brown 1982; Pant *et al* 1982; Pant and Katiyar 1983). Little is known about the effect of insecticides on water utilization in insects. This paper reports the effects of permethrin, a pyrethroid insecticide, on the water utilization in Eri-silkworm *Philosamia ricini* (Lepidoptera: saturniidae).

### 2. Materials and methods

Gravid females of *P. ricini* (collected from the original stock maintained separately at sericulture section—World Bank Research and Development Project) were allowed to

oviposit, (Sarkar 1980) in the laboratory. Egg layings were transferred to plastic trays and after 9–10 days, the freshly hatched larvae, were removed to separate terraria (plastic trays size  $36 \times 26 \times 4$  cm) and maintained in the laboratory fed *ad libitum* on castor leaves *Ricinus communis* at  $26 \pm 2^\circ\text{C}$  and  $70\% \pm 20$  ZRH. The test individuals were separately fed on (i) fresh castor leaves (ii) leaves treated with acetone (iii) leaves treated with permethrin (0.2 ppm) dissolved in acetone (permethrin, a pyrethroid insecticide, 20% EC supplied by Voltas India Ltd.). The concentration of permethrin was calculated on the basis of active ingredient and then used.

Fresh leaves of *R. communis* were cut into two halves, one half was weighed and given to the larvae and the other was used as control to determine the initial water content (Delvi and Pandian 1972). Larvae began feeding as soon as the leaf was offered. Fresh leaves were offered four times daily to minimise the amount of water evaporating from the leaves. However, the total error due to evaporation from leaves if left for 24 hr in the terraria is about 3.5% (Delvi 1983). Daily food intake was calculated following the standard gravimetric method described by Waldbauer (1968). The total water intake ( $C$ ) (mg water/insect/instar) was estimated by knowing the water content of the leaves offered (Delvi 1983). Rate of water intake is expressed in mg of water/mg live weight of insect/day. Water loss *via* defaecation ( $F$ ) was calculated from freshly defaecated pellets of randomly selected larvae on a glass dish, weighed and dried at  $90^\circ\text{C}$  to weight constancy. Such estimates were repeated at different times of the day and on all days of the experiments. Using total dry faeces weight values, the total water loss *via* defaecation was determined. Water lost through defaecation is expressed in terms of mg of water lost/insect/instar and rate of water loss through faeces in mg of water lost/mg live weight of insect/day. To estimate the amount of water retained in the body ( $P$ ), few larvae were dried just before commencing the respective feeding experiments and their water content was assumed to represent the initial water content of the larvae chosen for the respective experiments (sacrifice method of Maynard and Loosli 1962). The amount of water retained by larvae during a particular instar was estimated by subtracting the initial water content of the larvae of that particular instar from that of terminal larvae.

Some insects obtain atmospheric water through the integument (Bodine 1921; Ludwig 1937; Beament 1964) and in a few cases *via* the cloacal ends (Beament 1961) or *via* the spiracles (Buxton 1932). Body water is also lost to the atmosphere through the integument or *via* the spiracles during expiration (Uvarov 1966). The water losses through spiracles and cuticles are not easy to separate and both are usually considered together as transpiration (Uvarov 1966). The dynamic aspects of these physiological processes of absorption of atmospheric water and transpiration of body water through integument have been discussed by Wigglesworth (1957); Edney (1957, 1967); Eberling (1964); Cloudsley-Thompson (1962) and Beament (1964). The importance of water taken orally released through metabolism of fat, carbohydrate and protein in smaller insects, especially those feeding on carbohydrate rich leaves, is less (Schmidt-Nielsen and Schmidt-Nielsen 1953; Wharton and Arlian 1972; Delvi 1983). Perhaps, *P. ricini* acquires the required amount of water from the ingested *R. communis* leaves.

Water loss through transpiration ( $R$ ) was calculated by subtracting the water retained in the body ( $P$ ) from water absorbed ( $C - F$ ) using the modified IBP formula  $C = F + P + R$ . Water absorbed is expressed in mg of water/insect/instar and the absorption rate in mg of water/mg live wt of insect/day. Water absorption efficiency was calculated in percent relating ( $C - F$ ) to the amount of water intake ( $C$ ).

Transpiration is expressed in mg of water/insect/instar and the rate of transpiration in mg of water/mg live wt of insect/day.

### 3. Results and discussion

Total dietary water budget obtained for *P. ricini* fed *ad libitum* on fresh leaves of *R. communis* is presented in figure 1, as a function of life stage and age. In general the total dietary water intake steadily increased from its minimum of 70.9 mg during the first larval period to as much as 13635.3 mg during the final larval period, which amounts to 16174 mg from hatching to pupation. About 97% of the total dietary intake occurred during the final two larval periods.

As the life stages of *P. ricini* included different number of days (see figures 1 and 2) and as the larval body weight differed at different stages, dietary water input was related to the unit body weight (mg) per day (see also Delvi 1983). Rate of dietary water intake (figure 2) steadily decreased from its maximum of 3.14 during the first larval period to a minimum of 0.503 mg/mg live weight/day during the final larval period. Though the total water utilization (water absorbed or retained in the body or lost through faeces or transpired) increases with increase in body weight and age, the rates of water utilization always decreased with increase in body weight and age. Therefore these rates, which considerably differ in different larval periods, are inversely related to the body weight

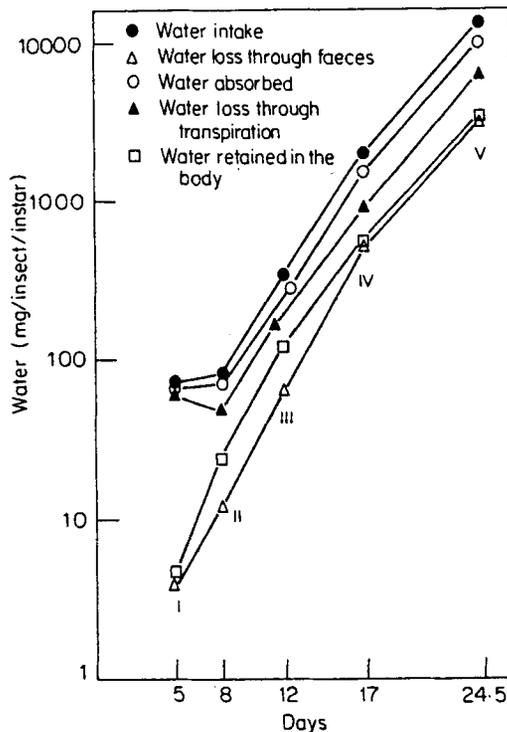


Figure 1. Water intake and utilization in *P. ricini* fed *ad libitum* on *R. communis* as a function of life stage.

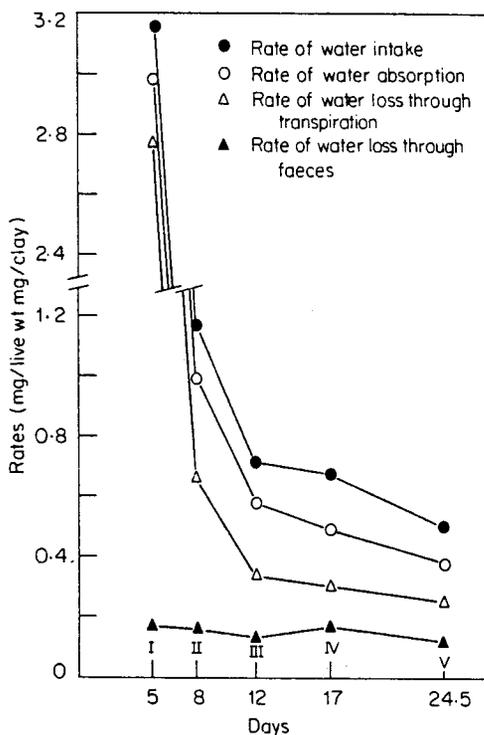


Figure 2. Rates of water intake and utilization in *P. ricini* fed *ad libitum* on *R. communis* as a function of life stage.

and age of *P. ricini*. This factor has been neglected by many authors (see Delvi 1983). As the metabolism generally follows the surface rule, it is evident that early larval periods (with large surface area per unit body weight) should have higher rates of metabolism. Therefore the difference in the rates of water absorbed or lost through faeces or transpired, can be purely a function of the size of the insect. This conclusion is significant in the light of the wide variations found in the rates of water utilization reported by previous workers for insects belonging to Lepidoptera and Orthoptera (Pandian *et al* 1978; Delvi 1983).

Dietary water intake in *P. ricini* was 16174 mg (table 1) from hatching to pupation. Water loss may be *via* (i) faeces (ii) from the silk worm at death and/or pupation (iii) transpiration. Since, the first 2 and the total water intake have been estimated, the dietary water loss *via* transpiration can be calculated. Almost 75% of the input water is absorbed and only 24.5% lost through faeces. However, as much as 65.2% of the absorbed water is lost through transpiration and only 34.8% is retained in the body. A notable feature is the range of variations, for instance, the amount of water input averaged 13635.27 mg during the last larval period with SD value of 649.33 mg (coefficient of variation  $cv = 4.7\%$ ). Similarly the range of variation was fairly high for water lost through faeces ( $cv = 6.6\%$ ) or through transpiration ( $cv = 8.9\%$ ) by the final instar larvae. Such wide variations in the water utilization have been reported by previous workers for other terrestrial insects (Pandian *et al* 1978; Delvi 1983). For instance, the monarch butterfly *Danaus chrysippus* retains 240 mg of water during the

Table 1. Effects of permethrin on water utilization in *P. ricini* fed *ad libitum* on *R. communis*.

Parameters	Nontreated		Acetone treated	Permethrin treated
	Hatching to pupation	Final 2 instars	Final 2 instars	Final 2 instars
Larval period (day)	24.5	12.5	13	13
Dietary water intake (mg/insect)	16173.98	15665.67	12515.04	8648.70
Water loss through faeces (mg/insect)	3965.44	3885.18	3126.72	1821.34
Water absorbed (mg/insect)	12208.54	11780.49	9388.32	6827.36
Water retained in the body (mg/insect)	4253.05	4101.88	2807.34	2084.28
Water loss through transpiration (mg/insect)	7955.49	7678.61	6580.98	4743.08
Water intake rate (mg/mg live weight/day)	1.2372	0.5881	0.6785	0.5399
Water loss rate through faeces (mg/mg live weight/day)	0.1525	0.1477	0.1493	0.1185
Water absorption rate (mg/mg live weight/day)	1.0854	0.4387	0.5293	0.4216
Water transpiration rate (mg/mg live weight/day)	0.8632	0.2772	0.3831	0.2900
Water absorption efficiency (%)	82.38	74.82	77.19	78.26

fifth instar with SD value of 87 mg ( $cv = 36.25\%$ ) and the variations for water intake, or absorbed or lost *via* faeces or transpiration ranged from about 9–15% (Pandian *et al* 1978). Probably, variations in dietary water utilization is closely related to variations in the utilization of matter. A close relationship exists between the efficiencies of matter assimilated and water absorbed in the grasshopper *Poeciloceris pictus* (Delvi 1983). The faster rate of water absorption in *P. ricini* during the first instar may be due to the high absorption efficiency of the larvae (82%). The high transpiration rate of 2.76 mg/mg live wt/day (figure 2) is correlated to the higher rate of water intake (3.14 mg/mg live wt/day) observed during the first instar.

Water absorption efficiency averaged 82.4% (table 1) and did not vary much from instar to instar though it gradually decreased from 94.6% in the first instar to 75.3% in the final instar.

Rates of dietary water loss *via* defaecation or transpiration (Koidsumi 1935; Uvarov 1948; Delvi 1983) followed the same trend as that of rates of water intake. The rate of water loss *via* faeces did not change appreciably from instar to instar and ranged from 0.17 mg/mg live insect/day during the first larval period to 0.124 mg/mg live insect/day during the final larval period (figure 2). The rate of water loss through transpiration decreased from its maximum of 2.76 during the first instar to a minimum of 0.249 mg/mg live wt/day and averaged 0.863 mg/mg live weight/day.

A survey of recent literature reveals the paucity of information regarding water utilization from hatching to death and or pupation. The only paper on water utilization published recently is that of Delvi (1983) which gives valuable data on water utilization of orthopteran *P. pictus* at 2 different temperature levels. For comparative purposes Delvi (1983) has also given data on *D. chrysippis* from hatching to pupation at 32°C. Studies on *D. chrysippus* (Pandian *et al* 1978) reveal water utilization during the fifth

instar larvae only. On the whole the lepidopteran *D. chrysippus* accumulates more water through faster rates of water intake and absorption, than *P. pictus*, to tide over the non-feeding pupal stage (Delvi 1983).

*P. ricini* passes through 5 instars in about 24 days with the final 2 instars lasting for about 13 days (table 1). Heavy mortality was observed during the first few instars of *P. ricini* when fed *R. communis* with permethrin. Lepidopteran larvae consume more than 97–98% of the total food intake during the final 2 instars (Waldbauer 1968) and accumulate sufficient water (Delvi 1983) and energy (Delvi and Pandian 1971) to tide them over the non-feeding pupal stage. Therefore, effects of insecticide on water utilization in *P. ricini* have been studied only in the last 2 larval stages.

The effect of permethrin on dietary water utilization in *P. ricini* is presented in table 1. The larvae took about 13 days to complete the final 2 instars when fed both normal castor leaves and permethrin treated castor leaves (figure 3). It was necessary to treat castor leaves with permethrin dissolved in acetone to obtain uniform spreading of permethrin and quick evaporation of the acetone. However, when only acetone-treated leaves were fed to *P. ricini*, the water utilization was affected considerably. Considering the values of *P. ricini* fed normal castor leaves as 100 the water intake was 79.9 or 55.2% with acetone or with permethrin. While acetone itself affected up to about 20% on water intake or absorbed or lost through faeces or transpiration, the values for permethrin fed *P. ricini* are in the range of about 40–50% (table 1). Hence, permethrin has considerable effect on the rates and efficiencies of water utilization. A significant decrease in the rate (table 2) of water utilization and production of smaller pupae and smaller adult moth, was observed. Srinivasan (1977) reported similar results for

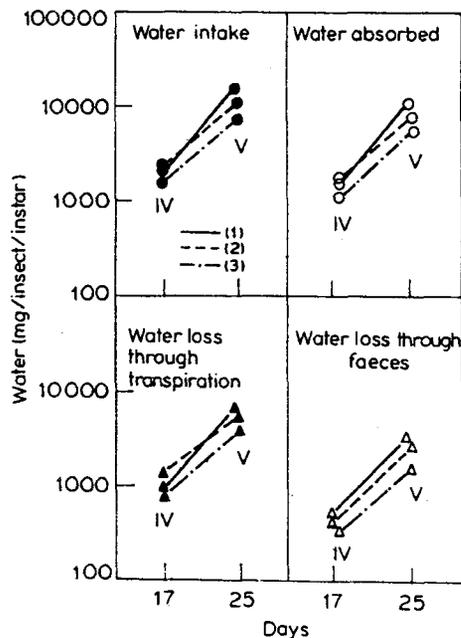


Figure 3. Effects of insecticide permethrin on water intake and utilization in *P. ricini* fed *ad libitum* on *R. communis* during the final two instars. (1) Fed non treated castor leaf, (2) Fed acetone treated castor leaf and (3) Fed permethrin treated castor leaf.

**Table 2.** Effects of permethrin on rates of water utilization in *P. ricini* fed *ad libitum* on *R. communis*.

Parameters	Nontreated		Acetone treated		Permethrin treated	
	IV	V	IV	V	IV	V
Life stage (instar)						
Water intake rate (mg/mg live weight/day)	0.673	0.5031	0.8439	0.5131	0.6272	0.4527
Water loss rate through faeces (mg/mg live weight/day)	0.1714	0.1240	0.1642	0.1343	0.1431	0.0939
Water absorption rate (mg/mg live weight/day)	0.4988	0.3786	0.6798	0.3788	0.4843	0.3588
Transpiration rate (mg/mg live weight/day)	0.3053	0.2490	0.5042	0.2619	0.3298	0.2502
Water absorption efficiency (%)	74.31	75.33	80.55	73.83	77.20	79.31

housefly larva of *Musca domestica*; live weight of the larva reared on milk pads soaked in 0.2% caffeine. Holometabolous insects accumulate substantial nutrient reserve during the final larval stage; which are chiefly deposited as fat and glycogen in their fat body (Gilbert 1964; Wyatt 1972). Formation of small pupae and adults and utilization of less water by larvae fed on permethrin treated castor leaves may be due to the effect of the toxin not only on the synthesis of the stored products, but also of proteins, an essential phenomenon in the growth of organisms. The mechanism by which insecticides inhibit the utilization of water could be through repellency, disruption of feeding physiology and other chronic toxicity possibly related to insecticide action (see also Ross and Brown 1982).

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