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Dietary water balance in a tropical insect

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Abstract. Dietary water intake of the tropical grasshopper *Poecilocerus pictus* fed *ad libitum* from hatching to death on the milkweed *Calotropis gigantea* averaged 85 or 51 g at 26°C and 171 or 78 g at 36°C for a female and male respectively. As much as 54 or 96 g dietary water is lost via faeces by a female at 26 or 36°C; the corresponding values for a male was 37.5 and 36.2 g. A male or female carried at death about 9 or 6% of the respective dietary water absorbed at 26 or 36°C. Water loss via exuvia amounted to 26 mg in all the series. Due to oviposition 4.8 or 7.4% of the total water absorbed was lost by a female at 26 or 36°C. There exist a very close relationship between the efficiencies of matter assimilation and water absorption. The high dietary water intake and absorption rates reported for the tropical lepidopteran *Danaus chrysippus* are correlated with the accumulation of water to meet the requirements during the nonfeeding pupal stage.

Keywords. Dietary water; *Poecilocerus pictus*; *Calotropis gigantea*; exuvia; transpiration; *Danus chrysippus*.

1. Introduction

Water is an important factor which controls the limits of distribution of terrestrial animals (Allee *et al* 1949). Insects form an important component both in terms of number or biomass and functional unit in terrestrial communities (Engelmann 1966). Experimental determinations of energy budget are known to offer most important clues in regard to the success of aquatic organisms (Kinne 1960; Brett *et al* 1969); data on the energy budget supplemented with water budget, are required to know the important clues with regard to the success of a terrestrial animal (Michael *et al* 1971; Reese and Beck 1978; Scriber 1977, 1979; Scriber and Slansky 1981).

Data on energy budget of a number of terrestrial insects (from hatching to death) have recently been reported (Delvi and Pandian 1971; Delvi 1972; Hiratsuka 1920; Schroeder 1971; Scriber and Slansky 1981; Delvi and Premaleela 1983). Some have considered the water balance of insects taking into account one or two physiological stages and instars (Pandian *et al* 1978; Baker and Lloyd 1970). Information on the water balance of an insect from hatching to death is scanty although the means and the extent of intake and loss of water are many, complex, interrelated and continuously oscillating.

Some insects are known to obtain atmospheric water through the integument (Bodine 1921; Lugwig 1937; Beament 1964) and in a few cases *via* the cloacal ends (Beament 1961) or the spiracles (Buxton 1932). On the other hand, body water may also be lost to the atmosphere through the integument or *via* spiracles during expiration

(Uvarov 1966). Water losses through spiracles and cuticle are 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 the integument have been dealt with by many workers (Wigglesworth 1957; Edney 1957, 1967; Eberling 1964; Cloudsley-Thompson 1962; Beament 1964 and Bursell 1964).

Relatively more water is taken orally; many insects are known to drink (Barton-Browne 1964), but others particularly stored-product pests and perhaps many leaf feeders get all or most of the water from the food ingested (Waldbauer 1968; Millot and Fontaine 1937; Lee 1961). Another possible internal source of metabolic water is *via* fat oxidation; 100 g fat upon oxidation is known to yield 107 g of metabolic water, 100 g carbohydrate yields 56 g water and 100 g protein yields 41 g water (Baldwin 1964). Such metabolic water is of great significance in large fluid-feeders (Schmidt-Nielsen and Schmidt-Nielsen 1953). However, its importance in smaller insects, especially those feeding on carbohydrate rich leaves is less (Wharton and Arlian 1972). Perhaps, *P. pictus* meets a major fraction of the required water from the ingested leaves of the milkweed *Calotropis gigantea.* Body water is also lost through faeces (which includes urine), exuvia egg and associated products and other secretions (eg. silk etc.). The quantitative aspects of water gain *via* food and loss *via* excretory and faecal products, as well as the mechanisms regulating them have not been studied adequately and the importance of such data to understand adaptive mechanisms in arthropods inhabiting different habitats has been emphasised (Vernberg and Vernberg 1971; Pandian *et al* 1978). This paper reports the dietary water budget of a tropical insect *Poecilocerus pictus* (Family: Pyrgomorphidae) reared from hatching to death at two different temperature levels.

2. Material and methods

The grasshopper *P. pictus* (15 to 25 individuals in each series) was reared in the laboratory feeding on the fresh leaves of *C. gigantea* from hatching to death at room temperatures of 26 ±2°C, 70 ±20% r.h. and 8 hr photoperiod and 36 ±2°C, 60 ±10% r.h. and 12 hr photoperiod. Fluctuations in relative humidity were in the range of ±10% in a day and ranged from 70 to 90% at any one time during a year. Insects transfer water into their blood from air at relative humidity as low as 70% (Beament 1964). Since the experiments at room temperature of 26°C were performed at an ambient r.h. of 70%, considerable amount of atmospheric water could have been transferred into *P. pictus*; however, this was not estimated separately. The water absorbed from the atmosphere was included in the changes in the body weight of *P. pictus.* At 36°C, the ambient relative humidity was 60% and hence the transfer of such water into *P. pictus* may be very limited.

Fresh leaves of the milkweed *C. gigantea* offered as test food for *P. pictus* were always culled from the same large plant growing in the University campus, cut and offered, following the standard procedure (Waldbauer 1968).

The test individuals normally feed immediately after the food is offered; the satiation time (the time from the commencement of feeding to voluntary cessation, Brett 1971), lasted 3 to 5 min in the first few instars and 8 to 13 min in subsequent instars and adults. During the first 30 min, the water loss owing to evaporation from the leaves in the terraria without insects averaged 4.3 ±0.4% at 26°C and 6 ±3.1% at

36°C of the total initial leaves given. Since half the food was consumed before 1/3 of the respective period, the water loss from the leaf might have been lesser than that estimated above; hence 1/3 of the estimated value *i.e.* 1.1% at 26°C and 1.5% at 36°C may be taken to assess experimental error in measuring the intake of water through food plant.

The water content and chemical composition of plants vary as function of age and season (Golley 1961). The leaves of *C. gigantea* are thick, leathery and contain an average water content of 86 ±1.5%. The variations in the initial water content of the leaves and the changes in the water content owing to transpiration and evaporation in the leaves during its presence in the terraria amount to 3.5%.

The faecal pellets produced by sample individuals of *P. pictus* belonging to different life stages and sex reared at 26 and 36°C were collected as they were being defecated and their respective water content estimated by drying in an oven maintained at 105°C, until weight constancy. Water content of the faeces at 26 or 36°C varied from 77 to 89%. Since the mean difference between the respective mean water contents of leaf and faeces was only 2.5%, water content of faeces and leaf was considered to be the same (see also for *P. pictus* Delvi and Pandian 1972, for *Schistocerca gregaria*, Phillips 1964). Dietary water retained in the body during different life stages was estimated by sacrificing sample individuals reared under the same conditions in the laboratory. Mean water content values of these individuals are presented as functions of life stage, sex and temperature in table 1. The SD value exceeded 5 only in very few cases. The average of all the SD amounted to 3 which is 4.1% (coefficient of variation) of the mean obtained for water content of different life stages. On the whole, the experimental error in estimating dietary water intake, loss *via* faeces and retention in the body may not exceed 8.9%.

Table 1. Mean water content of the grasshopper *P. pictus* fed *ad libitum* on *C. gigantea* at 26±2°C, 70±20% r.h. and at 36±2°C, 60±10% r.h.

	Female		Male	
	26°C	36°C	26°C	36°C
Hopper (Instar)				
I	79.7±0.03	79.7±0.03	79.7±0.03	79.7±0.03
II	77.3±1.66	72.5±1.7	75.6±2.8	72.8±5.1
III	80.7±2.3	74.5±2.1	75.9±4.2	71.0±1.2
IV	75.2±3.4	75.0±3.1	74.2±4.6	76.0±0.8
V	77.6±4.2	73.8±2.0	74.7±4.8	72.9±4.5
VI	77.1±2.1	77.97±4.9	74.8±1.2	74.2±3.8
Adult				
I fortnight	76.2±2.0	73.8±5.4	74.6±4.0	73.9±3.1
Before oviposition	67.8±3.1	—	74.9±3.5	—
After oviposition	60.2±2.9	—	66.6±5.4	—
At death	58.3±5.3	65.3±3.1	60.4±6.3	64.1±4.8

Each value represents the average of 10 to 25 animals, which were dried immediately after moulting.

3. Results and discussion

Mean values obtained for total dietary water intake of *P. pictus* as functions of life stage, sex and temperature are presented in tables 2 and 3. In general, total dietary water intake increased from the first instar to a maximum in the sixth instar (e.g. 17.5 g for females at 26°C, table 2) or in the first fortnight of the adult life (e.g. 41.2 g for females at 36°C, table 3). Mean total dietary intake amounted to 84.85 or 51.35 g for a female or male reared at 26°C, while it was as much as 170.8 g for a female and 78.1 g for a male reared at 36°C.

As the life stages of *P. pictus* included different days (see tables 2 to 7; column 2), dietary water intake was calculated in mg/day. Daily dietary water intake increased from about 12 or 36 mg in the first instar at 26 or 36°C to a maximum of 684 or 351 mg for a female and male respectively in the first fortnight of adult life at 26°C and to 2748 mg in the first fortnight of adult female or to 1151 mg in the sixth instar male at 36°C. Subsequently, the daily water intake decreased in all cases.

The mean dietary water intake rate was highest in the second instar female (558.8 mg/g/day) and male (771.7 mg/g/day) at 26°C, whereas it was over 1200 mg/g/day in the second instar male and fourth instar female at 36°C (table 3). In most cases, dietary water intake rate decreased with increasing body weight and age of *P. pictus*.

As indicated earlier, dietary water loss may be *via* (i) faeces, (ii) exuvia, (iii) reproductive products, (iv) from the grasshopper at death and (v) transpiration. Since the first 4 and total dietary water intake in *P. pictus* have been estimated, the dietary water loss *via* transpiration could be calculated. Mean total water loss *via*

Table 2. Dietary water intake in *P. pictus* fed *ad libitum* on *C. gigantea* at 26 ±2°C, 70 ±20% r.h., and 8 hr/day photoperiod.

Life stage stage	Average duration (day)		Middle body weight (mg)		Mean total water intake (g/instar)		Mean daily water intake (mg)		Water intake rate (mg/g/day)	
Hopper (Instar)	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
I	30	31	35.6	33.3	0.378	0.357	12.6	11.5	353.9	345.9
II	16	15	102.0	80.6	0.915	0.932	57.2	62.2	558.8	771.7
III	19	16	207.0	181.8	1.613	1.377	84.8	86.1	410.1	474.1
IV	21	24	393.4	376.0	3.091	2.419	147.2	100.8	374.2	268.1
V	27	32	912.1	797.5	8.114	6.989	300.5	218.4	329.5	273.9
VI	49	40	2011.0	1483.7	17.447	14.801	356.1	370.0	177.1	236.0
Adult (fortnight)										
I	15	15	3151.0	1984.0	10.265	5.258	684.3	350.6	217.2	176.7
II	15	15	3832.0	2240.0	8.576	5.090	571.7	339.4	149.2	151.5
III	15	15	4133.0	2270.0	8.274	3.763	551.6	250.9	133.5	110.5
IV	15	15	4328.0	2610.0	7.661	3.108	510.7	207.2	182.4	79.4
V	15	15	4615.0	2630.0	7.207	2.671	480.5	178.1	104.1	67.7
VI	15	15	4939.0	2435.0	4.906	2.293	327.1	152.9	66.2	62.8
VII	15	15	4939.0	2148.0	3.200	2.293	213.4	152.9	42.8	62.8
VIII	15	—	4939.0	—	3.200	—	213.4	—	42.8	—

Table 3. Dietary water intake in *P. pictus* fed *ad libitum* on *C. gigantea* at 36 ±2°C, 60±10% of r.h. and 12 hr/day photoperiod.

Life stage	Average duration (day)		Middle body weight (mg)		Mean total water intake (g)		Mean daily water intake (mg)		Water intake rate (mg/g/day)	
Hopper (instar)	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
I	15	17.4	42.1	39.2	0.547	0.476	35.8	27.4	849.2	689.9
II	9	9.7	91.5	93.0	0.769	1.029	83.5	106.2	849.2	1141.9
III	9	8.8	203.9	196.1	1.915	1.624	124.7	184.5	611.6	940.0
IV	9	9.0	375.7	389.0	4.218	3.414	444.0	379.3	1181.8	975.1
V	13	11.6	1033.7	801.2	11.197	7.236	835.6	623.7	808.4	778.5
VI	18	15.1	2270.8	1615.0	25.870	17.372	1437.4	1150.5	632.9	712.4
Adult (fortnight)										
I	15	15	4671.9	2410.4	41.221	15.748	2748.0	1049.9	588.2	435.6
II	15	15	6087.5	2713.7	21.593	7.322	1439.0	488.1	236.5	179.9
III	15	15	6525.0	2713.7	29.815	9.963	1987.6	664.2	304.6	244.8
IV	15	15	5881.4	2824.9	22.570	9.238	1504.6	615.8	255.8	217.9
V	15	15	5973.4	2889.6	11.119	4.689	741.3	312.5	124.1	108.1

Table 4. Dietary water loss of female *P. pictus* fed *ad libitum* on *C. gigantea* at 26 ±2°C. 70 ±20% r.h. and 8 hr/day photoperiod.

Life stage	Average duration (day)	Mean total water loss *via* faeces (g)	Rate of water loss *via* faeces (mg/g/day)	Mean total water loss *via* transpiration (mg)	Rate of water loss *via* transpiration (mg/g/day)
Hopper (Instar)					
I	30	0.255	238.2	86.5	80.9
II	16	0.433	264.6	411.0	251.8
III	19	0.867	220.3	664.9	169.0
IV	21	1.961	237.4	926.8	112.2
V	27	5.318	215.8	2794.6	89.1
VI	49	11.445	116.2	4949.3	50.2
Adult	105	33.874	639.4	13835.3	26.3

faeces and transpiration as function of life stages, sex and temperature are reported in tables 4, 5, 6 and 7. Water loss *via* faeces and transpiration at two temperature levels and water loss owing to egg laying were added up to present the total value for female adult. This was necessary as different test individuals oviposited during different fortnights.

Total water loss *via* faeces increased from about 0.25 g in first instar male and female at 26°C to a maximum of 11.44 and 9.89 g in the sixth instar female and male (tables 4 and 5). At 36°C maximum total water loss occurred during the sixth instar, the values being 10 g for male and 13.43 for female. From hatching to death, a female or male at 26°C lost 54.15 or 37.48 g dietary water *via* faeces, whereas the values at 36°C were 96.16 g or 36.26 g. It is evident that as much as 30.69 g or 13.87 g and 74.68 g or 41.85 g of dietary water was absorbed from hatching to death by a female

or male at 26 and 36°C respectively. In terms of assimilation efficiency (Delvi and Pandian 1971), water absorption efficiency was 36.1 or 27.0% at 26°C and 43.7 or 53.8% at 36°C for a female or male respectively. These values may be compared with the assimilation efficiency values reported by Delvi (1972) for *P. pictus* (26°C: male: 27% female: 33%; 36°C: male 56%, female: 58%). It can be seen that a close relationship exists between the efficiencies of matter assimilated and water absorbed.

Table 5. Dietary water loss of male *P. pictus* fed *ad libitum* on *C. gigantea* at 26 ±2°C, 70 ±20% r.h. and 8 hr/day photoperiod.

Life stage	Average duration (day)	Mean total water loss *via* faeces (g)	Rate of water loss *via* faeces (mg/g/day)	Mean total water loss *via* transpiration (mg)	Rate of water loss *via* transpiration (mg/g/day)
Hopper (Instar)					
I	31	0.243	234.2	82.4	79.8
II	15	0.554	457.8	339.6	280.8
III	16	0.731	251.2	539.6	185.5
IV	24	1.588	175.9	647.4	71.7
V	32	4.774	187.1	1767.6	69.3
VI	40	9.891	166.6	4346.8	73.2
Adult (fortnight)					
I	15	4.068	136.7	943.2	31.7
II	15	4.182	124.5	772.3	22.9
III	15	3.123	91.7	433.1	12.7
IV	15	2.579	65.8	529.0	13.5
V	15	2.133	54.1	481.1	12.2
VI	15	1.806	49.4	487.0	13.3
VII	15	1.806	56.1	487.0	15.1

Table 6. Dietary water loss of female *P. pictus* fed *ad libitum* on *C. gigantea* at 36 ±2°C, 60 ±10% r.h. and 12 hr/day photoperiod.

Life stage	Average duration (day)	Mean total water loss *via* faeces (g)	Rate of water loss *via* faeces (mg/g/day)	Mean total water loss *via* transpiration (mg)	Rate of water loss *via* transpiration (mg/g/day)
Hopper (Instar)					
I	15	0.307	486.4	215.8	341.7
II	9	0.391	474.3	329.2	399.7
III	9	0.840	457.7	951.7	518.6
IV	9	0.223	814.9	3743.6	1106.8
V	13	5.534	411.8	5053.8	376.1
VI	18	13.429	328.5	11268.8	275.6
Adult	75	75.433	945.0	42049.0	105.3

Table 7. Dietary water loss of male *P. pictus* fed *ad libitum* on *C. gigantea* at 36 ±2°C, 60 ±10% r.h. and 12 hr/day photoperiod.

Life stage	Average duration (day)	Mean total water loss *via* faeces (g)	Rate of water loss *via* faeces (mg/g/day)	Mean total water loss *via* transpiration (mg)	Rate of water loss *via* transpiration (mg/g/day)
Hopper (Instar)					
I	17.4	0.321	337.2	221.1	324.2
II	9.7	0.458	507.6	519.6	575.9
III	8.8	0.746	431.9	768.9	445.5
IV	9.0	1.617	461.6	1616.0	461.6
V	11.6	3.615	389.0	3143.7	338.2
VI	15.1	10.001	410.1	6618.9	273.1
Adult (fortnight)					
I	15	1.623	44.9	13729.2	235.0
II	15	3.276	80.4	3954.2	97.1
III	15	6.001	147.4	3962.3	97.3
IV	15	5.003	118.8	4065.1	95.9
V	15	3.675	86.4	306.1	7.0

Table 8. Water balance of *P. pictus* and *D. chrysippus* fed *ad libitum* on *C. gigantea*.

Parameter	*P. pictus* 26°C		*P. pictus* 36°C		*D. chrysippus* 32°C	
	Female	Male	Female	Male	Female	Male
Intake	84.847	51.351	170.838	78.111	3.689	3.511
Absorption	30.694	13.873	74.681	41.855	1.916	2.000
Loss via						
(a) Faeces	54.153	37.478	96.157	36.256	1.773	1.511
(b) exuvia	0.026	0.026	0.026	0.026	—	—
(c) reproduction	4.548	—	5.519	—	—	—
(d) transpiration	23.168	12.597	64.615	39.614	1.186	0.865
(e) at death pupation	2.952	1.250	4.521	2.215	0.730	1.135
					Mean of ♀ and ♂	
Intake rate	270.4	284.0	734.6	473.4	1453.4	
Absorption rate	97.6	76.7	321.0	254.7	790.7	
Transpiration rate	73.6	69.7	277.7	241.0	415.9	
Efficiency of water absorption (%)	36.1	27.0	43.7	53.8	51.9	56.9

The value for items 1 to 3 are given in g, and those from 4 to 6 in g/g live insect/day.

Rates of dietary water loss *via* defecation or transpiration (Koidsumi 1935; Uvarov 1948) followed the same trend as that of rates of dietary water intake. The rate of water loss *via* faeces was maximum during the second instar at 26°C in female (264.6 mg/g/day) or male (457.8 mg/g/day) and at 36°C in male (507.6 mg/g/day). The transpiration rate in female or male at 26°C was 251.8 or 280.8 mg/g/day (second instar) and in male at 36°C was 575.9 mg/g/day. Rates of water loss *via* faeces or transpiration in females at 36°C was maximum during fourth instar (*via* faeces 814.9: *via* transpiration: 1106.8 mg/g/day). From these respective maxima, the rates of water loss *via* transpiration and defecation decreased as a function of life stage. On the whole, water lost through transpiration in a female or male was 23.17 g or 12.597 g at 26°C, whereas it was as much as 64.615 g in a female or 39.614 g in a male at 36°C (table 8).

Jakovlev and Kruger (1953) reported transpiration rate for a number of grasshoppers. The recalculated values (expressed in mg/g/day) from the basic data reported by them are: 374.4 and 175.7 for male and female of *Chorthippus apricarius* respectively; 326.9 or 191.5 for male or female of *C. parallelus*; 207.4 or 102.2 for male or female of *C. brunneus*; 265 or 132.5 for male or female of *Omocestus viridulus*; 185.8 or 119.5 for male or female of *Mecostethus grossus*; 169.9 or 102.2 for male or female of *Oedipoda caerulescens.* It can be seen from tables 4 to 7 that the transpiration rates reported for the adult *P. pictus* are low, when compared to those of Jakovlev and Kruger (1953). The values reported for *P. pictus* represent only a fraction of the total transpiration, *i.e.* only the dietary water transpired and not total transpiration as in the case of Jakovlev and Kruger (1953). Secondly, the life stage of the grasshoppers studied by them has not been reported; perhaps, they have used different life stages of different species, as their values reported range from 102.2 to 374.4 mg/g/day.

The mean dietary transpiration rate for the entire life span (average transpiration rate, from hatching to death is calculated as the mean transpiration rates of all instars and adult stages of the animal giving due consideration for the duration of each life stage) amounted to 73.6 or 69.7 mg/g/day for female or male *P. pictus* at 26°C and 277.7 or 241 mg/g/day for female or male at 36°C. The mean dietary water transpiration of *D. chrysippus* (from hatching to pupation) at 32°C was recalculated to be 415.9 mg/g/day. In *D. chrysippus* (final instar only) the transpiration rate of water increased from 208 mg/g live insect/day at 20°C to 337, 420 and 1127 at 25, 30 and 35°C, respectively (Pandian *et al* 1978). It is evident that the transpiration rates of *P. pictus* at 36°C or *D. chrysippus* at 32°C are nearly 4 times faster than those obtained for *P. pictus* at 26°C. The transpiration rate of water seems to increase with the increase in temperature.

Total water loss *via* exuvia increased from 0.2 mg in the first instar to 16.6 mg in the sixth instar in either sex and the tested temperature levels. The total water lost *via* exuvia was 2.6 mg. A female or male *P. pictus* at death contained 2.95 or 1.25 g at 26°C and 4.52 or 2.22 g at 36°C. *P. pictus* oviposited minimum twice at 26°C or 3 times at 36°C; the number of eggs oviposited ranged from 127 to 457, along with the oviposited eggs a froth like substance was also deposited. Since oviposition last for over 1 to 3 hr, the flowing froth-like substance began to evaporate, therefore water lost *via* oviposition was estimated by determining the water content of sampling individuals reared at 26 and 36°C before and after ovipositions. Water loss owing to oviposition in a female averaged 4.548 g at 26°C and 5.519 g at 36°C.

Dietary water budget of the tropical orthopteran *Poecilocerus pictus* as functions

of sex and temperature is presented in table 8. For comparison, dietary water budget of a tropical lepidopteran *Danaus chrysippus* obtained by recalculating the basic data of Delvi (unpublished) is also given in table 8. The water loss owing to the transfer of sperm in male *P. pictus* has not been estimated, but it should be negligible. Hence water loss *via* transpiration in male individuals at both temperature levels included a small fraction of water loss due to the sperm transfer. The mean dietary water intake and absorption rate for the entire life span amounted to 270.4 or 97.6 mg/g/day for a female and 284 or 76.7 mg/g/day for male at 26°C respectively. A female or male absorbed 36 or 27% of the total dietary water, about 75.4 or 90.8% of the absorbed water was transpired and 0.09 or 0.19% was lost *via* exuvia (table 8) and 9.6 or 9% at death. A female *P. pictus* lost only 14.8% of water *via* oviposition.

A more or less similar pattern of dietary water distribution is seen in *P. pictus* reared at 36°C. The major differences between individuals reared at two temperatures may be summarised as follows: (i) The rate of dietary water intake or absorption at 26°C did not differ much as a function of sex and averaged 277.3 or 86.6 mg/g/day; at 36°C these values were 734.6 or 321 and 473.4 or 254.7 mg/g/day for a female or a male respectively. (ii) Mean water absorption efficiency varied little with sex and was about 31% at 26°C and 48.7% at 36°C; the water absorption efficiency decreased as the life stages advanced at 26°C; the efficiency values did not significantly vary among individuals belonging to different life stages at 36°C. (iii) A female lost as much as 14.8% water *via* oviposition at 26°C, whereas it was only 7.4% in individuals reared at 36°C. (iv) A female or a male transpired 75.4 or 90.8% at 26°C while the values were 86.5 or 94.6% at 36°C. (v) Male and female individuals carried about 9% of the total dietary water absorbed at death at 26°C, those at 36°C carried only about 6 and 7%. Owing to oviposition a female at 26°C lost 14.8% of the total absorbed water while at 36°C it lost 7.4%.

From the point of view of transpiration rate, water budget of *D. chrysippus* at 32°C is more comparable to that of *P. pictus* at 36°C. Average dietary water intake or absorption rate for *P. pictus* at 36°C, from hatching to death, amounted to 734.6 or 321, 473.4 or 254.7 mg/g/day for female or male respectively. The corresponding value for *D. chrysippus* (dietary water intake rate 1453.4 mg/g/day and absorption rate 790.7 mg/g/day) is approximately 2 to 3 times faster. However, the efficiencies with which water was absorbed in *P. pictus* at 36°C (48.7%) and *D. chrysippus* (54.4%) were more or less similar. The fraction of absorbed water carried by *D. chrysippus* (49.2%) prior to pupation, though not strictly comparable to *P. pictus* at death (about 6% at 36°C), was far high; at 36°C male and female *P. pictus* belonging to sixth instar contained 13 and 9.3% of the respective absorbed water before undergoing final moult. The high fractions of absorbed water contained by *D. chrysippus* before pupation may be an adaption to tide over the non-feeding pupal stage (Hackman 1971).

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