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DRY MATTER UTILIZATION AND ECOLOGICAL EFFICIENCIES IN LARVAE OF A PYRALID MOTH, *DIAPHANIA INDICA* SAUNDERS (LEPIDOPTERA)

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Feeding experiment on immature stages of *D indica* have been elaborated to discuss the food utilization, ecological efficiencies and producer-consumer link on dry matter in a primary consumer. On an average 186.72 mg was the total ingested food resulting into 9.88% of the tissue growth in four larval stages. The AD had been the landmark of nutritional quality whereas ECD as the net growth efficiency for transforming assimilated food into the caterpillar's biomass. CI and GR with poor values are suggestive for the suitability of the food on which a herbivore has fed The most significant role of the herbivore had been to process the accumulated part of the food to different trophic levels in a food chain.

INTRODUCTION

Diaphania indica Saunders associated defoliating cucurbit plant *Lagenaria vulgaris* Ser. as a primary consumer in its larval stages caused vital injury to the crop productivity. Hiratsuka (1920) though initiated the study on food consumption and utilization which was later elaborated over several lepidopterous caterpillars by Evans (1939). For proper understanding of the nutritional behaviour of insects Soo Hoo & Fraenkel (1966), Waldbauer (1968), Mukerjee & LeRoux (1969), Delvi & Pandian (1972), Mehrotra *et al* (1972), Kogan & Cope (1974), Singh *et al.* (1975) and Gupta & Vats (1980) made their respective studies. Such estimation of different growth parameters helped to foretell the amount of food passing from one trophic level to another via ingestion. The present study is an attempt to explain an interaction between the producer-consumer link based on quantitative food utilization of four stadial periods in two sexes of a pyralid moth on dry weight basis.

MATERIAL AND METHODS

For gravimetric measurements, the neonate caterpillars of *D. indica* were fed on the weighed tender part of the fresh bottle gourd leaves. The pre-weighed caterpillars were also kept in 25 separate petri dishes. After every 24 hrs larvae, unconsumed leaves and egesta were weighed by a Monopan balance (Royalwor). For moisture correction, a parallel sample of control was run in another petri dish without caterpillar. On getting the pupa, the caterpillars were assigned the respective sex. Thus the daily recording of basic parameters *viz.* the body weight, ingestion and egestion on live weight basis were maintained till the adult emergence. The so collected daily samples of the unconsumed leaves and egesta were oven dried at 60°C till a constant weight was achieved. Five individuals of each instar and 25 individuals of I instar were oven dried, reweighed and calculated for the dry weight per mg of live body. The values of dry weight per mg of live weight both of leaf and caterpillar were multiplied with recorded live weight values. The indices of food utilization (ingestion, assimilation, tissue growth, respiration) and ecological efficiencies (AD = approximate digestibility, ECD = efficiency of conversion of digested food, ECI = efficiency of conversion of ingested food, CI = consumption index, GR = growth rate) were calculated at dry weight basis after Waldbauer (1968).

RESULTS

Consumption and utilization of food (Figs. 1-3)

An individual caterpillar of *D. indica* in its average life span having 4 instars of 16 4 days ingested cucurbit leaf in dry matter of 186.72 mg. The instar-wise ingestion was 0.5620±0.0306 to 28.9817±2.3631 mg ind^{-1} d^{-1}. The male caterpillar fed more at I and IV instars than the female of II and III instars. Also the feeding at IV instar was 71 69% more than I to III instars. A male caterpillar ingested instarwise 9.2482, 3.3862, 5.1071 and 3.2056 mg dry food for one mg of the body weight whereas a female 8 8610, 3.3162, 4.6035 and 2.9499 mg in respective instars with maximum values being in the middle of an instar. Such feeding resulted into an increased body weight by 58.1911 mg and 31.16% of the ingested food, male being higher (59.7754 mg) than a female (57.1299 mg). 84.54% was an accumulation in the biomass at IV instar compared to I to III instars. Similarly an individual caterpillar assimilated 81.0088 mg and 43 38% of the food ingested However, 0 5052±0.0259 to 10.8421±0.8299 mg were the assimilated values ind^{-1} d^{-1} wherein the male being superior over the female. The assimilation curve followed the consumption trend with more divergence observed at the last instar.

Moreso, the food consumption and utilization experiment in a larval life span resulted an excretment of 105.7119 mg and 56.61% of the food ingested. For one mg of excretment an individual caterpillar required 25.6846, 11 4384, 12.8955 and 2.2592 mg of live food instarwise. Though the egestion ind^{-1}d^{-1} was 0.05680$\pm$0 0067 to 18.1396$\pm$2.1512 mg but the IV instar alone egested 91 08%, much higher than values obtained for I to III instars. Thus the daily spectrum of egestion showed high values during the latter instars and likewise the trend of consumption. Nevertheless, the tissue growth per caterpillar was 132.1922 mg having a total growth at IV instar 62.31% higher than I to III instars. Per caterpillar, the tissue growth obsereved 18.6258 mg and 9.98% of the food ingested but with identical values in both the sexes. For the unit mg of growth, a caterpillar utilized 16.0354, 6.9263, 5 6435 and 10.4160 mg of dry leaves in its respective stadial periods. The respiration being a vital activity, remained more at IV instar and 28.72% higher than I to III instars having successive increase instarwise ind^{-1} d^{-1}. Estimating the total respired values 62.3471 mg per individual, 33.39% of

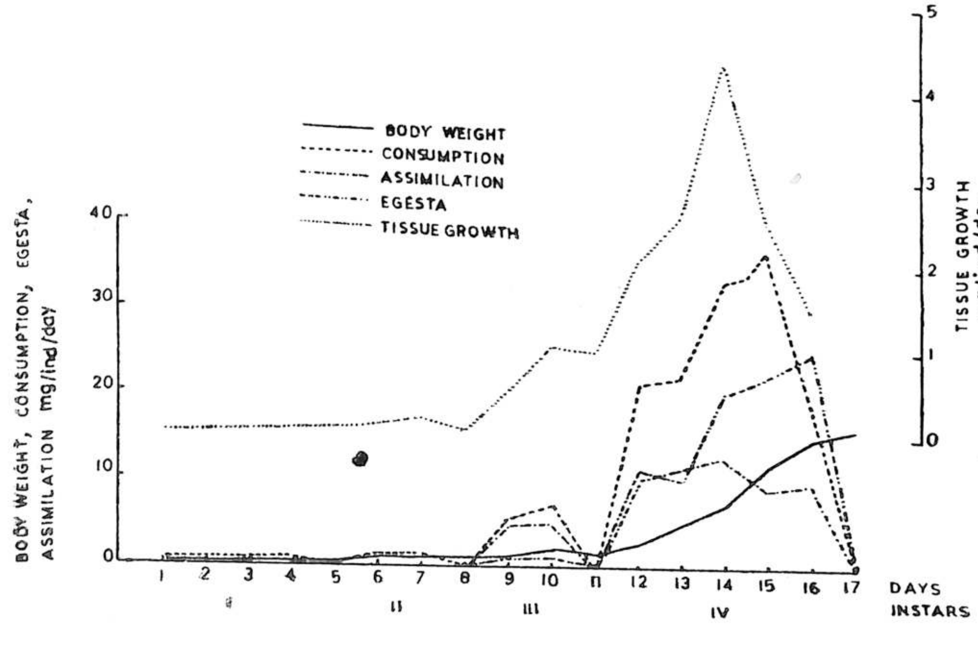

Fig 1. Average values of different parameters of food utilization for *D. indica* on dry weight basis.

ingested food and were much higher in the female (38.15%) compared to a male (27.10%) (Table I).

Ecological efficiencies (Fig. 4)

The approximate digestibility (AD) observed highest (89.5055±1.1006%) at I instar which successively declined with an increase in age of the caterpillar upto 45.4656±3.4618% at last instar. Such pattern of AD is suggestive for a change in the nature of the ingested food. A male caterpillar instarwise superseded the female except the IV instar where female happenes to be efficient in AD than the male. Further, poor digestibility observed was at dry weight basis rather than live since ind^{-1} d^{-1} average estimated being 72.41% in their total larval period. During first three instars, the percentage digestibility remained higher (89.5055±

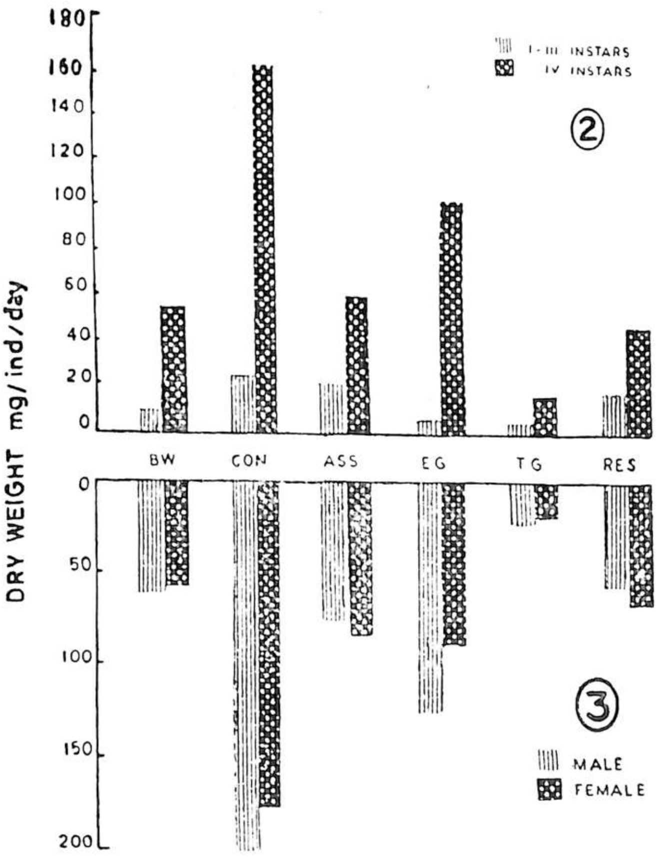

Fig 2 Food utilization of *D. indica* in two phases of their larval span on dry weight basis. 3. Food utilization profile of *D. indica* in both the sexes on dry weight basis.

Table I. Distribution of feeding values at different parameters per individual of *D. indica* at dry weight basis (Percentage values in parenthesis).

Instars	Sex	Ingestion	Assimilation	Egestion	Tissue Growth	Respiration
I–II	M	5.88	5.15 (87.59)	0.74 (12.59)	0.56 (9.52)	4.59 (78.06)
	F	6.03	5.09 (84.41)	0.94 (15.59)	0.68 (11.28)	4.41 (73.13)
	A	5 97	5.11 (85.58)	0.86 (14 41)	0.64 (10.58)	4.48 (75.00)
III–IV	M	194.30	69.07 (35.55)	125 22 (64 45)	19.40 (9.98)	49.67 (25 56)
	F	171.63	80.48 (46.89)	91.15 (53.11)	17.05 (9.93)	63.37 (37.16)
	A	180.75	75 90 (41.99)	104.85 (58 01)	17.99 (9.96)	57.87 (32 02)
I-IV	M	200.18	74.22 (37.08)	125 96 (62 92)	19.96 (9.97)	54 26 (27.11)
	F	177.66	85.57 (48.17)	92.09 (51.83)	17.73 (9.98)	67.78 (38.15)
	A	186 72	81.01 (43.38)	105.71 (56.61)	18.63 (9.98)	62.35 (33.39)

M = Male; F = Female; A = Average

1.006 to 75.8314±4.6469%) whereas the last instar approximated half the value of I instar. Instead of earlier instars with flattened peak (I, III instars),the flattened peak slant at IV instar was slightly declining and lower than ECD. Instarwise ECD dry observed increasing I to last instar (6.5498±0.8764 to 29.6520±2.2948% ind^{-1} d^{-1}) where male being higher in growth efficiency (20.3956%) than a female (17.7616%) against a total average of 18.8482%. Though the graphics of ECD and ECI dry at I to III instars followed similar trend but the ECD dry obtained much higher than ECI and AD at IV instar, having a single peak system. The average ECI in total larval span of four instars estimated 11.41% ind^{-1} d^{-1} higher for the female (11.56%) than a male (11.31%). The average CI calculated was 5.1430 mg/mg of dry weight per day and almost similar in the two sexes (5.2178 male, 5.0932 female). Though the declining pattern of CI is identical to AD but the value being 3 62 times higher at I instar than the last instar. Corresponding to CI, the GR has been declining instarwise, where male observed having higher values at all the four instars and being better (0.2920 mg/mg ind^{-1} d^{-1}) than an average (0.2870 mg/mg ind^{-1} d^{-1}).

Producer-consumer link Vs productivity

The growth and development of a herbivore remained directly correlated with accumulation of the biomass which spontaneously gets dispersed and utilized into different metabolic activities, part of it being reserved for future completion of non-feeding life stages like pupa and the adult emergence. The standing crop of 1143 39 mg of *L. vulgaris* contributed 63.47% to standing crop of the first order consumer and 36.54% recycled back to the soil as unutilized food. With 85.58% of standing crop consumed by first two instars of I-phase (I, II instars) per individual showed 14 41% as unutilized food, 75% released to the atmosphere and only gaining 10.58% as net productivity Compairing the values in II-phase (III, IV instars) though has much greater part of the available standing crop of producer (96 80%) led to 41 99% as assimilated, 58 01% egested, 32.02% dissipated to atmosphere and 9.96%as net productivity, It is now estimated that with an increase in the age of caterpillar, the loss harnessed by autotroph was much vital. Contribution by both the sexes at I instar is almost indentical while III to IV instars contribution by male was more compared to a female (II instar being an exception). Accumulation of food for secondary consumers remained 4.34 times higher by II instar than I instar, 5.67 times higher by III instar of II instar, and 3.23 times higher by IV instar as compared to the III instar on biomass basis.

An individual caterpillar of *D indica* throughout its larval span on an average consumed 186.72 mg dry food accumulating 58.19 mg biomass ind^{-1}, and 31.16% of the food consumed in the form of body weight. With an increase in age, about 52 folds increase from I to IV instars have been the removal of producers biomass. The male caterpillar contributed more (200 10 mg ind^{-1}) than a female counterpart (177 66 mg ind^{-1}) in all the four instars Based on the biomass estimated at different parameters resulted into an increase by 31.16% in the body weight of the food ingested ind^{-1} whereas on the other hand 43.36% was assimilated into herbivores body. The herbivores contribution then had been eliminating 56.61% in the form of undigested food to the soil and 33.39% made available as gases to the atmosphere. The most significant role of herbivore was to accumulate dry matter 9.98% of the total consumption and 23% of the food assimilated and made available to the next trophic level in an Eltonian pyramid.

DISCUSSION

The feeding experiment on nutritional behaviour of *Diaphania indica* Saund. characterized a gradual increase in body weight during the successive instars to compensate the energy utilized at each ecdysis and further to support an internal preparedness for the moulting and pupation. A male caterpillar ingested 14 30% more food than female in its larval period. Mukerji & Guppy (1970) also reported higher ingestion for a male caterpillar of *Pseudaletia unipuncta*. The amount of food ingested at the beginning of a stadial period of *D. indica* was higher than towards the end which supports an observation made by Mukerji & LeRoux (1969). During the last two instars of *D. indica,* the

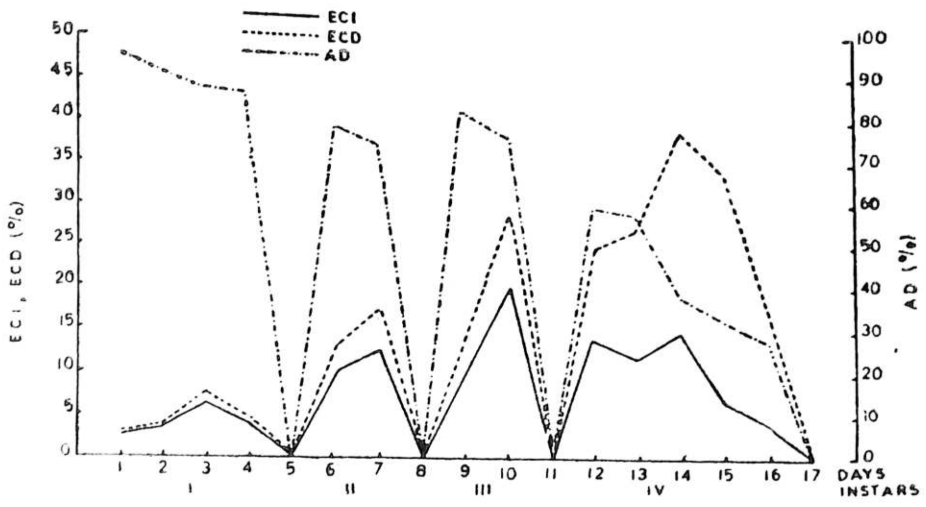

Fig. 4. Average values of ecological efficiencies for *D indica* on dry weight basis.

maximum food consumed was 96.80% per individual of total ingested food. Waldbauer (1968), Schroeder (1971), and Kogan & Kope (1974) further endorsed maximum consumption in Lepidoptera by the last two instars of *Bombyx*, *Hyalophora cecropia* and *Pseudoplusia includens*. According to Bailey & Singh (1977) the last instar of *Memestra configurata* only accounted for 80.10% on dry weight of the total ingestion while *D. indica* ingested 86.92% during the IV instar. This increase in ingestion during last instars was an adoption to tide over the excessive requirement of energy for non-feeding pupal stage and in an adult female for ovipositional activities in particular (Kogan & Cope, 1974; Poonia, 1978). The weight specific ingestion in *D. indica* decreased with the increase in age except of III instar. So the maximum ingestion per mg of body weight had been in I and III instars which is in support to Chlodny (1967). Vats *et al.* (1977) also reported an inverse decline in weight specific consumption with an increase in biomass in *P. brassicae* larvae. The female caterpillars of *D. indica* observed heavier at I to III instars. Mathavan & Bhaskaran (1975) recorded the male heavier than female in the larval period of a danid butterfly. The loss in body weight at each moult was due to the feeding stopal in the premoulting stage and an elimination of exuviae in postmoulting stage.

The assimilated food was the net quantity available to the caterpillar to be incorporated into body substances and to metabolize for various body requirements. An increase in assimilation with an enhanced food ingestion in the present observation was in support to Bailey & Singh (1977) and Mackey (1978). The female caterpillar of *D. indica* assimilated more food than the male except I instar. But Singh *et al.* (1975), Singhal *et al.* (1976) and Vats & Kaushal (1981) observed considerably higher assimilation value for the males than the females on dry weight basis in orthopteroid insects. The more divergence between the assimilation and consumption curves of *D. indica* during the latter instars resulted into higher rate of egestion. Therefore, *D. indica* characterized 85.58% assimilation in first two caterpillars and 41.99% in last two instars. On an average, the caterpillar of *D indica* egested 55.61% of the total ingested food. The caterpillars of *D. indica* further required 25.68 to 2.26 mg of live food instarwise to egest one mg of excreta Schroeder (1971) and Mathavan & Pandian (1974) recorded 2.1 and 1.4 mg food consumption for defecating one mg of egesta in *Hyalophora cecropia* and *Danaus chrysippus* during the last instars respectively According to Kumar (1983) *Diacrisia obliqua* consumed 101.61 to 1.69 g of fresh sunflower leaves at I to last instar stages as to egest 1 g of faeces. During the last instar of *Philosamia ricini* Reddy & Alfred (1979) observed that 13 g of live castor leaves produced 1 g of egesta. Thus by knowing the amount of egestion of a particular species of either instar, the quantum of ingestion be estimated and vice-versa. The rate of egestion ind^{-1} d^{-1} at the last two instars was poor for the female caterpillar of *D. indica* than the male. This supported more accumulation of the food reserves in the female for ovipositional activities. The egestion and ingestion remained correlated with each other and as also been reported by Mukerji & Guppy (1970) and Vats & Kaushal (1980) in their respective studies.

A gradual increase in the tissue growth of *D. indica* observed with maximum growth being at last instars. The tissue growth during the last two instars was 96.56% of the total tissue growth in their total larval period. Schroeder (1972), Bailey & Singh (1977), and Vats & Kaushal (1980) reported 90.0, 95 44 and 88 78% of the total tissue growth during the last two instars in their respective lepidopteran species on dry weight basis. Chockalingam (1979) for *Pericallia ricini* reported that of the total assimilated food, 39% was utilized in tissue growth. Reddy & Alfred (1979) described that the last instar caterpillars of *Philosamia ricini* consuming 4 60 g and assimilated 2.92 g of food on live weight basis to produce 1 g of body tissue. In case of *D. indica* the last caterpillar consumed 903.91 mg of food and to assimilate 503.85 mg of cucurbit leaves as to produce 1 mg of tissue growth. Major amount of food ingested was utilized for the various body processes of immature caterpillars in both the sexes. The metabolic activities remained directly proportional to the rate of ingestion. In early instars of *D. indica* maximum food was used in maintenance and part of it in tissue growth.

Amongst the ecological efficiencies of *D. indica*, approximate digestibility is an ability to digest the ingested food, metabolize and convert the food-stuff into body substances. According to Phillipson (1966) AD also reflected on the proportion of ingested food available to be passed on to the next trophic level. The AD of *D indica* declined I to last instars in both the sexes and similar tendency is generalized by Bhattacharya & Pant (1976) and Scriber & Slansky (1981) in Lepidoptera. Waldbauer (1968) further added that this generalization is commonly observed for phytophagous insects. Further the spectrum of assimilation efficiency of *D. indica* suggested the partition of the larval period in two phases. The first phase (I, II instars) with high values (84.17%) of AD depicted that the caterpillar feeds over the soft leafy tissues and in the second phase (III, IV instars) with declined AD (68 65%) the caterpillar chewed over the mature leaves with thick and crude fibre contents, Kasting & McGinnis (1962) and Waldbauer (1964) concluded that such variations were because of the preferential feeding of the caterpillar during different larval stages. The per day average values of AD of *D. indica* were 45.47 to 89.51% on dry weight basis. Similar observations for AD were also recorded by Evans (1939) as 53 to 92% in *Smerinthus populi* on live weight basis. The last instar AD got half of the Iinstar in *D. indica* corroborating Evans (1939). Thus the assimilation efficiency be used as a landmark for the nutritional quality of the host plant.

The net growth efficiency (ECD) of *D. indica* suggested that the latter instars are more efficient in transforming assimilated food into caterpillars biomass. The parallel graphics of early stage of *D. indica* with little difference in ECD and ECI depicted the relatively high digestibility of cucurbit leaves and more divergence in the latter instars due to poor digestibility Kogan & Cope (1974) and Vats & Kaushal (1980), however, reported a decreasing tendency in the values of ECD. During the present study on *D. indica*, the ECI increases instarwise which further declined approaching the day of moult within an instar. Waldabauer (1968) further suggested that this decline is partially due to the concomitant decline in digestibility of the food. The declining trend of CI of *D. indica*, with an average value of 5.1431 mg/mg of dry body/day studied was in support to Bhattacharya & Pant (1976). The high value of CI indirectly indicated an unsuitability of the food on which the insect has fed. Further Fraenkel (1959) and Prasad & Bhattacharya (1975) also reported higher CI with the non-nutritive characteristics of the food plant. The CI live is greater than CI dry in *D. indica* which according to Waldbauer (1964) was probably a better measure of the behavioural response to the food whereas the CI dry defined to a nutritional response. The growth rate values of *D. indica* were 0.2437 to 0.3559 mg/mg of dry body/day and very much within the range described by Scriber & Slansky (1981) *i e.* 0.03 to 1.50 mg/mg of dry body/day for herbivorous caterpillars. The growth rate remained inversely related to the ECI and ECD. However, Schroeder & Malmer (1980) correlated the growth rate based on dry matter with gross efficiency (ECI) but not with net efficiency of growth (ECD). The last instar only ingested 79.06% of total consumed food, so the maximum damage to host plant caused by this instar. Due to high AD, the early instars are considered the most suitable stages for the control measures.

The spectrum of producer-consumer link of *D. indica* revealed that a major part of consumed food goes to soil as unutilized food in the form of excreta. According to Odum *et al.* (1962) that egesta still remained in the first trophic level, it is no longer available to the insect but available to other consumer such as bacteria or dietritis feeders. *D. indica* in its larval period assimilated 43.38% and accumulated 9.98% in the form of tissue growth for the second trophic level. Bailey & Mukerji (1977) reported for an orthopteran insect, *Malanoplus bivittatus* that it assimilates 40.62%, and utilized 15.67% energy of ingested food in tissues growth. However, Odum & Smalley (1959) estimated for a grasshopper that it assimilates a smaller percentage of ingested food but converts nearly 40% of the assimilated material into protoplasm.

Considering the phase analysis of food consumed at biomass values (3.2%) in I-phase, the greater values of assimilation (85.58%), poor of egestion (14.14%) and high rate of respiration (75%) supported an efficient utilization of the food which immediately processed for high metabolic activities, with almost no residual undigested material. This phase is assigned to be a vital period of highest growth and development in the life span of *D. indica*. But the values obtained in the II-phase of third and fourth caterpillars though are very high in percent food consumption (96.8%) but are 41.99% for assimilation, 58 01% egestion, 32.02% for respiration amphasizing low assimilatory and respiratory activities but tremendously increased perccntage for egesta. Evidently the II-phase contributed less to growth and development but mainly remained engaged in the maintenance and supporting activities of the larval body. Moreover, poor tissue growth in I-phase as compared to II-phase inspite of high rate of assimilation and lesser egestion indicated that the chemieal energy generated from respiration in the former is stored and utilized for the increased tissue growth in the latter phase. This assumption gets suppoted by (a) much higher rate of respiration in I-phase indicating high energy generation, (b) lower rate of respiration in II-phase inspite of more tissue growth and (c) higher rate of egestion inspite of poor assimilation in II-phase indicating the amount of unutilized food inspite of more energy requirement for the tissue growth. The net secondary productivity looked upon with less of variability 10.58% in I-phase and 9.96% in II-phase from an average value obtained for all the four instars *i. e.* 9.98%.

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