NUTRITIONAL PERFORMANCE OF *PIERIS BRASSICAE* (LEPIDOPTERA: PIERIDAE) FED ON THREE CRUCIFEROUS CULTIVARS

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ABSTRACT: *Energy budgets were evaluated for the larval development of Pieris brassicae fed on the leaves of Brassicae oleracea var. capitata (cabbage), B. oleracea var. botrytis (cauliflower) and B. campestris (mustard). Food consumption, assimilation and tissue growth values were maximum for the larvae fed on B. campestris than those of B. oleracea var. capitata and B. oleracea var. botrytis. Mean values of approximate digestibility (AD), efficiency of conversion of digested food into body tissue (ECD) and efficiency of conversion of ingested food into body tissue (ECI) fall in the range of reported values for lepidopterans.*

Key Words: *Lepidoptera, Pieris brassicae, Nutritional Indices, Cruciferous cultivars*

I. INTRODUCTION

Cabbage butterfly is a serious pest of cruciferous plants like cabbage, cauliflower, raddish and mustard (Kaushal and Vats, 1983; Jogar et al., 2005; Rather and Azim, 2009; Hasan and Ansari, 2010; Cahil and Kular, 2013; Sadozai and Khan, 2014) and non-cruciferous plants (Ovsyannikova and Grichanov, 2009). *Pieris brassicae* originated from Europe and infests 91 species of plants from 12 families (Someya et al., 2007).

The quality and quantity of host plants significantly affects the life history of *Pieris brassicae* by affecting the survival rate of different development stages, sex ratio and reproduction (Scriber and Slansky, 1981; Hasan and Ansari, 2010). Food consumption and utilization link plant attributes with insect performance (Slansky, 1990). The factors determining nutrient availability for growth and maintenance over a given period of time of development are the amount and type of food consumed and the efficacy with which it is utilized.

A number of workers have carried out considerable amount of work on the energy flow through different larval stages of lepidopterans (Kaushal and Vats, 1983; Cohen and Patana, 1984; Lazraevic and Mataruga, 2003; Arghand et al., 2011; Bagheri et al., 2011; Namin et al., 2014).

The main objective of the present study was to provide an approximation of energy flow through the larval stages of *P. brassicae* fed on three cruciferous cultivars: *Brassica oleracea* var. *capitata* (cabbage), *Brassica oleracea* var. *botrytis* (cauliflower) and *Brassica campestris* (mustard) under laboratory conditions. The results of this research will provide useful information for designing comprehensive pest management strategies against the cabbage butterfly.

II. MATERIALS AND METHODS

Plant sources: Leaves of three plant materials viz. *Brassica oleracea* var. *capitata* (cabbage), *Brassica oleracea* var. *botrytis (cauliflower), Brassica compestris* (mustard) were given for feeding larvae till completion of their life-cycle.

Laboratory Colony: Eggs of *Pieris brassicae* were collected from three different plant leaves and kept in moist petri-dishes until their hatching. On emergence, the larvae were transferred to three food plants in glass beakers (11.0 cm x 9.0 cm) covered with muslin cloth and were maintained in laboratory conditions at 23±1ºC, 75±5% RH and fed with natural diet of above mentioned plant leaves.

Newly hatched larvae were collected from the stock culture and divided into 5 replicates for each of the three plants having 10 larvae up to 2nd instar and 5 larvae in the next consecutive instars and transferred into glass beakers by fine mesh net for ventilation. Fresh leaves were fed daily to the larvae. Some dry tissue papers were also placed on top of wet cotton to maintain the freshness of the leaves provided to the larvae. The beakers were cleaned every day to avoid the risk of humidity and diseases.

Before the start of the experiment, each larva was weighed and provided with fresh food. After 24 h of feeding, the larvae, the unconsumed leaves and the egesta were collected. The larvae were weighed. The unconsumed leaves and the egesta were oven dried at 80ºC for 48 h till a constant weight was reached. Dry weight values of food plants and larvae were converted into calorific values. Larvae which died during the course of the experiment were replaced by the larvae of approximately the same age from the stock culture maintained for each host plant. Food consumption was calculated as the difference between the initial weight of the leaves provided and the weight of unconsumed plant material at the end of the experiment, after correcting for weight loss in the food material due to respiration and transpiration within this period. Dry weight equivalents of the food consumed were estimated from the percentage of the dry matter in all the three plant species separately. Percentage dry matter was obtained by oven drying of fifteen samples of the leaves of each species at 80ºC. The dry weight was expressed as a percentage of the weight of the fresh foliage. Nutritional indices (weight gain, food consumed, faeces produced and various efficiencies of food utilization) were calculated as described by Waldbauer (1968). Assimilation was calculated by subtracting the weight of faecal matter from the weight of the food consumed, while increase in body weight was taken as a measure of tissue growth.

Ecological efficiencies were calculated as follows:
Approximate digestibility = Assimilation/ Consumption x 100
Tissue growth efficiency = Tissue growth/ Assimilation x 100
Ecological growth efficiency (ECI) = Tissue growth/ Consumption x 100

III. RESULTS AND DISCUSSION

The data on duration of instars, consumption, egesta, assimilation and tissue growth are presented in Table1.
No significant difference was observed in the duration of larval instars fed on three food cultivars.
Consumption: The caterpillars consumed a total of 3763.65 cal, 2783.4 cal and 3811.97 cal of cabbage, cauliflower and mustard leaves, respectively. The percentage requirements of food for the consecutive stages calculated from total consumption for the whole development period were: 5.38, 6.16, 17.57, 25.26 and 45.63% on cabbage; 4.26, 4.73, 6.61, 40.69 and 43.71% on cauliflower; 4.06, 4.5, 13.67, 24.42 and 53.35% on mustard leaves. Feeding behaviour of *P. brassicae* larvae, showed strong preference for *B. oleracea* var. *capitata* and *B. campestris* than *B. oleracea* var. *botrytis*.
The steep increase in the amount of food consumed during third, fourth and fifth instars was due to the change in the way the larvae feed and the duration of these instars. The larvae of the first and second instars feed on the bottom of the leaves, eating chiefly the soft palisade tissue and epidermis. In the later instars, the larvae disperse and feed upon small veins containing more cellulose which is poorly digested (Vats and Kaushal, 1980). The food of the larvae in the later stages contains less palisade tissue, which is a factor deciding the amount of plant mass consumed. The nutritional requirements of an insect are associated with biomass and the duration of immature stages. Similar observations have also been observed by other scientists (Schroeder, 1976; Vats and Kaushal, 1980). Total consumption value for *P. brassicae* was higher on cabbage and mustard cultivars than cauliflower. More than 70% of the total food was consumed by the last two instars because of their higher weight; this is the case for all three food plants. Naseri et al. (2012), Bisht et al. (2012) and Namin et al. (2014) also observed maximum consumption in the last two/three instars of lepidopteran larvae. Bailey and Singh (1997) reported that sixth instar larvae of *Mamestra configurata* alone consumed 80% of the total ingestion.
Egesta: Higher consumption in the fourth and fifth instars resulted in higher production of egesta by the larvae. These two instars accounted for more than 85% of the total egestion. Curvilinear and positive relationship was observed for the supplied food plants when egestion on all three food plants in the present study was plotted against food consumption (Fig.1 a-c).
The quantity of egesta produced on three cultivars in the present study, is comparable to Waldbaur's (1964) observations on *Protoparce sexta* and Namin et al., (2014) on *Heliothis armigera* which produced different amounts of egesta when fed on different food plants. This is explained by differences in digestibility.
Assimilation: A total of 3695.88 cal, 2624.79 cal, and 3615.77 cal were assimilated by the larvae feeding cabbage, cauliflower and mustard leaves, respectively. The last two instars larvae assimilated 70.63% of cabbage, 84.06% of cauliflower and 76.99% of mustard leaves. Assimilation increased from first instar to last instar on all the food plants (Table 1). A positive relationship existed between food assimilation and consumption (Fig. 2 a-c). Mackey (1978), Kaushal and Vats (1983), Namin et al. (2014) also reported an increase in the amount of food assimilated with increased food consumption.
Tissue growth: The distribution of tissue growth in the fourth and fifth instars was: 56.46% of total tissue growth on cabbage, 65.41% on cauliflower and 73.77% on mustard.
Fig.3 (a-c) represents the relationship between consumption and tissue growth. 90% to 95% of the total

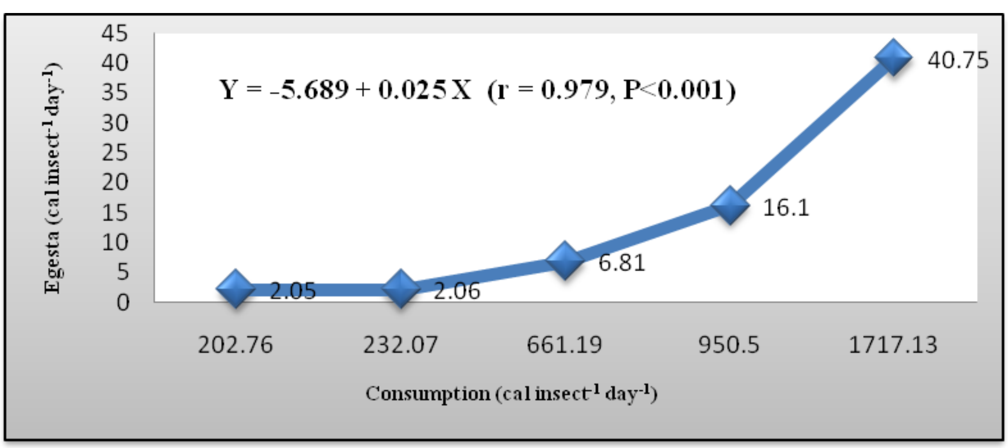
tissue growth occurred in the last two instars of *Platysomia cercopia* (Schroeder, 1973), *Manestra configurata* (Bailey and Singh, 1977), *Helicoverpa armigera* (Namin et al. 2014).
Thus from the data on consumption and tissue growth in the present study, it was observed that mustard was the most suitable food plant than cabbage and cauliflower. Probably quality of food was responsible for the maximum tissue growth and is in agreement with findings of Naseri et al. (2010) and Namin et al. (2014) who reported that quality and digestibility of food source are often major factors limiting herbivore growth.
Efficiencies of food utilization: Physical and chemical aspects of host plants and physiological characteristics with each other (Foss and Rieske, 2003). Percentage values of approximate digestibility and the efficiencies of conversion of ingested and digested food into body tissue are summarized in Table 2.
Maximum values of approximate digestibility (AD) were obtained for the first instar larvae and minimum for the last instar larvae on all food plants. Mean AD on cabbage was 98.8%, 95.8% on cauliflower and 97.0% on mustard. Mean values of AD recorded in the present study fall in the range of reported values (Vats and Kaushal, 1980; Bisht et al., 2012; Namin et al., 2014).
ECI is a measure of an insects ability to incorporate ingested food into tissue growth and ECD, as a parallel parameter, indicates the proportion of digested food converted into net insect biomass (Nathan et al. 2005).
Tissue growth efficiency or the efficiency of the conversion of assimilated food into body tissue (ECD) was not observed in set pattern. Mean ECD values obtained for cabbage, cauliflower and mustard were: 2.84%, 10.42% and 8.13%, respectively. Efficiency of conversion of ingested food into body tissue, or ecological efficiency (ECI) did not show any set pattern from first to last instar larvae. Mean ECI in the present study was 2.79% for the larvae fed on cabbage, 9.77% for those on cauliflower, and 8.75% for those on mustard.
Similar to other studies (Naseri et al., 2010; Arghand et al., 2011; Namin et al., 2014), it was also observed in the present study that nutritional responses for third to fifth instars of *P. brassicae* were different from each other.
Insect growth is directly correlated with nutrient input, lapidopteran larvae when fed high nutrient food showed better growth compared to those fed nutrient-poor food (Hwang et al. 2008). Thus, the values of AD, ECD and ECI show that mustard was the best food for the larvae followed by cabbage and cauliflower.

Table 1: Duration of instar, consumption, egesta, assimilation and tissue growth in *Pieris brassicae* larvae fed on three host plants

Stage	Duration of instar (days)	Consumption (cal insect^{-1} day^{-1})	Egesta (cal insect^{-1} day^{-1})	Assimilation (cal insect^{-1} day^{-1})	Tissue growth (cal insect^{-1} day^{-1})
***Brassica oleracea* var. *capitata* (cabbage)**					
1st instar	4.9 ± 0.87	202.76 ± 4.43	2.05 ± 0.02	200.71 ± 4.41	1.02 ± 0.01
2nd instar	4.6 ± 0.54	232.07 ± 2.88	2.06 ± 0.02	230.01 ± 2.89	2.73 ± 0.07
3rd instar	4.6 ± 0.54	661.19 ± 4.80	6.81 ± 0.03	654.38 ± 4.79	30.54 ± 6.77
4th instar	4.8 ± 0.44	950.50 ± 7.03	16.10 ± 0.15	934.4 ± 6.92	28.60 ± 1.08
5th instar	6.4 ± 0.54	1717.13 ± 18.49	40.75 ± 1.12	1676.38 ± 17.92	80.93 ± 3.03
***Brassica oleracea* var. *botrytis* (cauliflower)**					
1st instar	4.0 ± 0.94	118.43 ± 5.20	1.64 ± 0.15	116.79 ± 5.17	0.54 ± 0.18
2nd instar	3.6 ± 0.54	131.75 ± 7.92	2.24 ± 0.04	129.51 ± 7.88	4.50 ± 2.30
3rd instar	4.6 ± 0.54	184.04 ± 9.10	12.28 ± 1.92	171.76 ± 7.65	63.05 ± 9.91
4th instar	5.4 ± 0.54	1132.36 ± 7.64	36.62 ± 12.24	1095.74 ± 8.30	61.94 ± 6.82
5th instar	6.6 ± 0.54	1216.82 ± 10.92	105.82± 5.09	1110.99 ± 11.69	66.84 ± 5.53
***Brassica campestris* (mustard)**					
1st instar	4.0 ± 0.81	155.01 ± 3.71	0.70 ± 0.13	154.31 ± 3.58	1.74 ± 0.07
2nd instar	4.4 ± 0.54	171.17 ± 5.27	0.24 ± 0.42	170.93 ± 6.22	3.22 ± 0.21
3rd instar	4.6 ± 0.54	520.96 ± 8.21	14.51 ± 3.77	506.45 ± 6.75	86.17 ± 9.83
4th instar	4.6 ± 0.54	931.17 ± 7.54	37.81 ± 5.72	893.36 ± 2.91	123.70 ± 8.77
5th instar	6.6 ± 0.54	2033.66 ± 7.89	142.94 ± 5.53	1890.72 ± 2.62	132.79 ± 6.12

Table 2: Effficiencies of food utilization in *Pieris brassicae* larvae fed on three host plant species (mean ± SD)

Stage	Approximate digestibility (AD) (%)	Tissue growth efficiency (ECD) (%)	Ecological growth efficiency (ECI) (%)
***Brassica oleracea* var. *capitata* (cabbage)**			
1st instar	99.98± 0.01	0.50± 0.01	0.50±0.01
2nd instar	99.10 ± 0.01	1.18± 0.03	1.17± 0.03
3rd instar	98.96 ± 0.00	4.66± 1.03	4.61±1.01
4th instar	98.3 ± 0.01	3.05± 0.12	3.00±0.12
5th instar	97.42± 0.05	4.82± 0.19	4.71±0.19
***Brassica oleracea* var. *botrytis* (cauliflower)**			
1st instar	98.60± 0.13	0.47± 0.16	0.46±0.16
2nd instar	98.28± 0.07	3.40± 1.55	3.34± 1.53
3rd instar	93.34± 0.79	36.56± 4.42	34.12± 4.01
4th instar	96.76± 1.06	5.65± 0.65	5.46± 0.57
5th instar	91.29± 0.41	6.01± 0.52	5.49± 0.45
***Brassica campestris* (mustard)**			
1st instar	99.54± 0.07	1.12±0.02	5.59± 0.02
2nd instar	99.85± 0.24	1.77± 0.21	1.87± 0.07
3rd instar	97.21± 0.68	16.96± 1.81	16.52± 1.62
4th instar	95.94± 0.58	13.83± 0.94	13.27± 0.83
5th instar	92.96± 0.24	7.01± 0.31	6.52± 0.28



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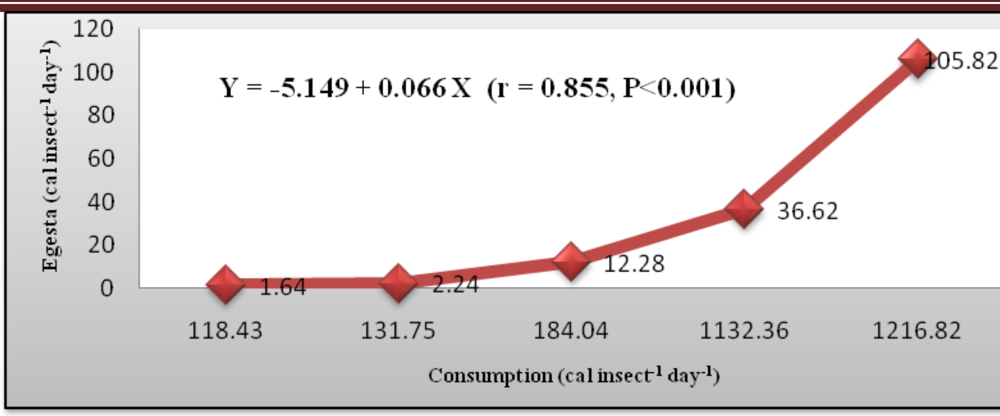

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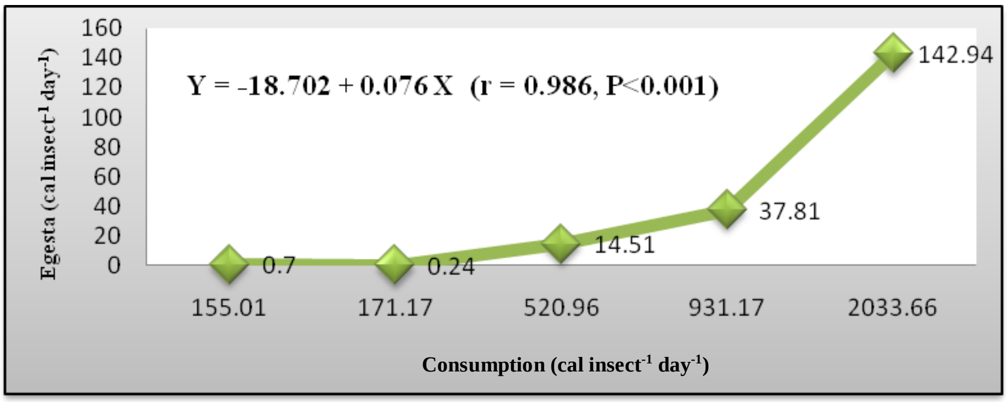

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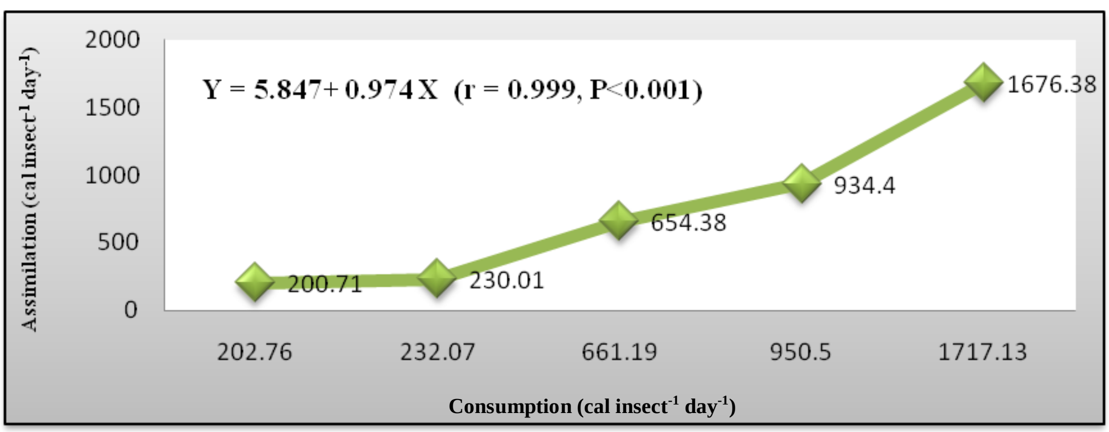
Fig. 1: Relationship between consumption and egesta. (a) ***Brassica oleracea*** **var. c*apitata* (cabbage), (b)** ***Brassica oleracea*** **var.** ***botrytis*** **(cauliflower), (c)** ***Brassica campestris*** **(mustard)**



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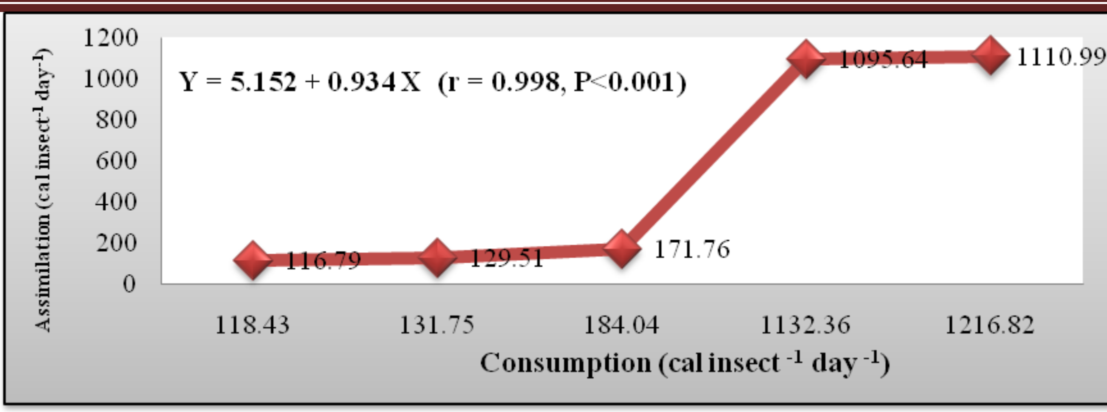

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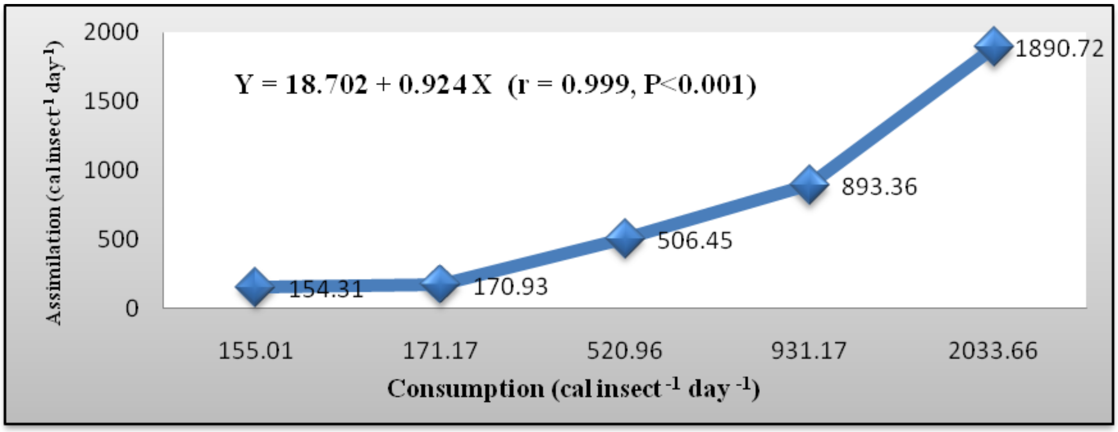
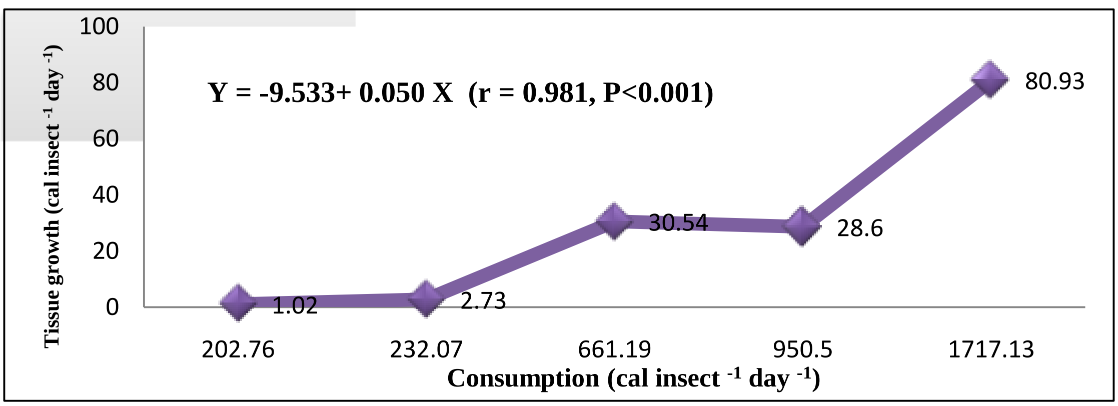


(c)

Fig. 2: Relationship between consumption and assimilation. (a) *Brassica oleracea* var. *capitata* (cabbage), (b) *Brassica oleracea* var. *botrytis* (cauliflower), (c) *Brassica campestris* (mustard)



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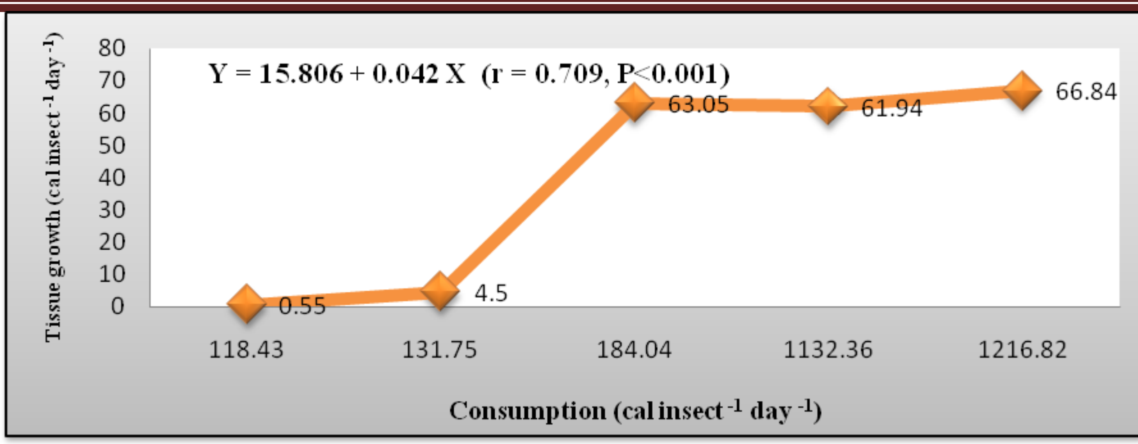

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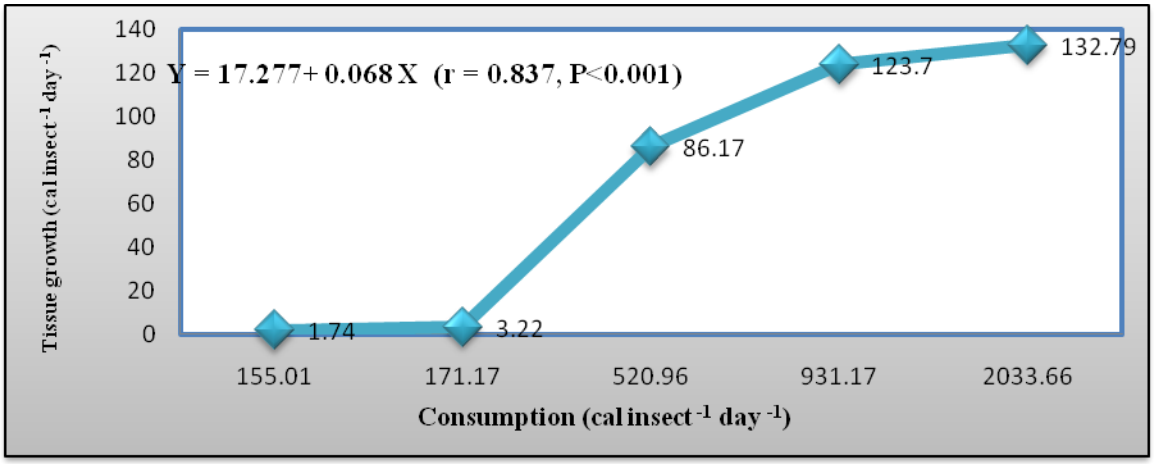

(c)

Fig. 3: Relationship between consumption and tissue growth. (a) *Brassica oleracea* var. *capitata* (cabbage), (b) *Brassica oleracea* var. *botrytis* (cauliflower), (c) *Brassica campestris* (mustard)

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