

*Department of Entomology, University of Wisconsin, Madison, USA, and Cereals Entomology,  
International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India*

## **Innate differences in consumption and utilization of food by the fast- and slow-growing larvae of cabbage looper, *Trichoplusia ni* (Hübner) (Lep., Noctuidae)**

By H. C. SHARMA and D. M. NORRIS

### **Abstract**

Consumption and utilization of soybean leaves by the fast versus slow-growing larvae of the cabbage looper, *Trichoplusia ni* were studied under laboratory conditions. Fast-growing larvae consumed more food/unit of body mass, and gained weight 10 times faster than the slow-growing larvae. Slow-growing larvae were less efficient in consumption and utilization of food, and the differences in indices of food utilization were greater between the fast- and slow-growing larvae on the relatively resistant soybean cultivar, "PI 227687" than on the susceptible cultivar, "Davis". Implications of differences in growth rates and food utilization by the fast- and slow-growing larvae on resistant and susceptible cultivars are discussed in relation to evolution of new biotypes and host-plant resistance.

### **1 Introduction**

Insect populations are genetically diverse, and this increases their capability for survival and reproduction. The genetic variation quite often is not expressed phenotypically, but is evident in terms of adaptation to different host-plants, developmental rates, resistance to insecticides or tolerance to other population suppression factors. Some variation is density dependent and results in selection for an array of traits within a population, which may reduce competition between individuals of the same species (PRICE 1976).

A small proportion of natural and laboratory populations of the cabbage looper, *Trichoplusia ni* have a slow rate of growth (TIGNOR and EATON 1986; SMILOWITZ and SMITH 1970). Selection for larval rate of development leads to immediate divergence for fast- and slow-growing larvae in *Cnephasia jactatana* (Walk.) (OCHIENG-ODERO 1990). Fast- or slow-growth of the larvae is controlled by genes regulating the release of prothoracotropic hormone in *Sarcophaga argyrostoma* R.-D. (BROADLEY and SAUNDERS 1986).

The present studies were carried out to determine whether the slow growth rate of *T. ni* larvae is due to innate differences in consumption and utilization of food. We also examined the effects of an insect-resistant ("PI 227687") and a susceptible ("Davis"), soybean cultivar on the growth of fast- and slow-growing larvae.

### **2 Materials and methods**

#### **2.1 Insects**

Larvae of *T. ni* were reared on a pinto bean-based artificial diet (SHOREY and HALE 1965) under laboratory conditions ( $25 \pm 1^\circ\text{C}$  and  $65 \pm 5\%$  relative humidity). Larval development was monitored in the rearing cups (100 ml), and newly molted third-instar larvae were used for studying the consumption and utilization of food. Fast-growing larvae molted into third instar in about 10 days after egg laying while the slow-growing larvae molted into third-instar in about 18 days.

## 2.2 Plants

Plants of "PI 227687" and "Davis" soybeans were grown in the greenhouse at the U. S. Dairy Forage Research Center, University of Wisconsin, Madison. Seeds of "PI 227687" and "Davis" were treated with thiram, and germinated in sterilized moistened vermiculite in a 27 × 27 × 7 cm plastic tray kept inside a Percival incubator at 27 ± 1°C and 16 h photophase. Seedlings at cotyledon opening were transplanted into 20 cm diameter earthen pots containing a sterilized mixture of soil, sand and vermiculite (2:2:1). Plants were watered daily, and kept under 16 h photophase using Metalarc® high-intensity (1000 Watt) lights. Total light intensity gave 28–36 moles of photon flux. Plants were fertilized at 15-day intervals with Miracle Gro® (11 g/2.78 l water) (Sterns' Nursery Inc., Geneva, N. Y.), and sprayed with 2.5 % safer® (50.5 % potassium salts of fatty acids) (Agro. Chem. Inc., Lyons Valley Road, Jamul, Ca.) to control white flies and thrips.

## 2.3 Consumption and utilization of food

Consumption and utilization of fully expanded soybean leaves were studied on trifoliolate number 8 at V10 stage of development (FEHR et al. 1971). A freshly detached leaf was weighed on a Mettler® balance and placed in a 9 cm diameter, 5 cm deep plastic cup. The cups were covered with a lid having a 9 cm diameter filter paper moistened with 2 ml water. There were 10 replications for each cultivar and category of larvae. Four-hour-starved pre-weighed larvae were confined with the leaves for two days. The cups were kept in a 27 × 27 × 7 cm plastic tray, which was covered with a similar inverted tray. Five leaves of each cultivar were similarly placed in plastic cups, but without larvae, to record the natural loss of mass in the leaves. The cups were placed in an incubator at 28 ± 1°C. At the end of the feeding period, the uneaten leaves, faeces, and larvae were separated, and placed in a drying oven at 80 ± 2°C for 24 h, and then the dry mass was recorded. Larvae were killed with benzene before drying. At the beginning of experiment, 10 larvae were individually weighed, and then dried in the oven to compute an initial mean dry mass of the larvae. Various indices on consumption and utilization of food were calculated on a dry mass basis as described by WALDBAUER (1968). Significance of difference between treatment means was determined by using paired t-test. Correlation coefficients between different indices of food utilization were also computed.

## 3 Results

There were significant differences ( $P < 0.05$ ) in consumption and utilization of food by the fast- and slow-growing larvae of the cabbage looper, *T. ni* (table 1). Dry mass of the slow-growing larvae at the start of the experiment was much higher than that of the fast growing larvae. Fast-growing larvae consumed more food per unit of body mass (CI) compared with the slow-growing larvae. Differences in consumption index (CI) between the fast- and slow-growing larvae were greater on the relatively insect resistant cultivar, "PI 227687" (CI 3.3 for fast-versus 0.6 for the slow-growing larvae) than on "Davis" (CI 2.8 for fast-versus 1.0 for the slow-growing larvae).

Table 1. Consumption of food by the fast- and slow-growing larvae of *T. ni*

Cultivar	Type of larvae	Initial wt. of larva (mg)	Mass of larva after the feeding period (mg)	Mass of food ingested (mg)	Mass of feces produced (mg)	Consumption index (CI)
PI 227687	Fast-growing	2.9 ± 0.2 <sup>a</sup>	11.6 ± 1.6 <sup>a</sup>	47.4 ± 9.9 <sup>a</sup>	11.8 ± 0.6 <sup>a</sup>	3.3 ± 0.5 <sup>a</sup>
	Slow-growing	18.0 ± 0.4 <sup>b</sup>	20.0 ± 0.4 <sup>b</sup>	24.3 ± 1.9 <sup>b</sup>	15.3 ± 1.5 <sup>a</sup>	0.6 ± 0.01 <sup>b</sup>
'Davis'	Fast-growing	3.6 ± 0.4 <sup>a</sup>	13.4 ± 1.1 <sup>a</sup>	48.0 ± 7.1 <sup>a</sup>	19.7 ± 2.6 <sup>a</sup>	2.8 ± 0.2 <sup>a</sup>
	Slow-growing	17.4 ± 1.2 <sup>b</sup>	20.6 ± 1.8 <sup>b</sup>	41.1 ± 2.8 <sup>a</sup>	28.0 ± 1.8 <sup>a</sup>	1.0 ± 0.1 <sup>b</sup>

Figures followed by the same letter in a cultivar for fast- and slow-growing larvae are not significantly different at  $P < 0.05$ .

Differences in growth rates between fast- and slow-growing larvae were significant ( $P < 0.05$ ) (table 2). Fast-growing larvae grew about 10 times faster than the slow-growing larvae. Differences in growth rates (GR) were also reflected in the efficiency of conversion of ingested (ECI) and digested (ECD) food into body matter. Slow-growing larvae were significantly less efficient compared with fast-growing larvae in ECI (8.5 to 9.3 % versus 20.9 to 21.3 %) and AD (29.3 to 37.3 % versus 58.3 to 71.3 %). Differences in ECD between fast- and slow-growing larvae were significant ( $P < 0.05$ ) only on "PI 227687".

Table 2. Indices of food utilization by the fast- and slow-growing larvae of *T. ni*

Cultivar	Type of larvae	Growth rate (GR)	Efficiency of conversion of ingested food (ECI%)	Approximate digestibility (AD%)	Efficiency of conversion of digested food (ECD%)
'PI 227687'	Fast-growing	0.572 ± 0.042 <sup>a</sup>	22.8 ± 4.5 <sup>a</sup>	71.3 ± 4.0 <sup>a</sup>	31.9 ± 8.8 <sup>a</sup>
	Slow-growing	0.052 ± 0.002 <sup>b</sup>	8.5 ± 1.0 <sup>b</sup>	37.3 ± 1.5 <sup>b</sup>	22.5 ± 1.9 <sup>b</sup>
'Davis'	Fast-growing	0.576 ± 0.020 <sup>a</sup>	21.3 ± 1.7 <sup>a</sup>	58.3 ± 0.9 <sup>a</sup>	37.1 ± 3.4 <sup>a</sup>
	Slow-growing	0.083 ± 0.022 <sup>b</sup>	9.3 ± 2.0 <sup>b</sup>	29.3 ± 2.5 <sup>b</sup>	32.6 ± 6.1 <sup>a</sup>

Figures followed by the same letter in a cultivar for normal- and slow-growing larvae are not significantly different at  $P < 0.05$ .

Correlation coefficients between CI versus GR, ECI and ECD were negative for the larvae fed on "PI 227687", and positive for the larvae fed on "Davis" (except CI versus GR, ECI and ECD for the slow-growing larvae) (table 3). Correlation coefficient between CI versus AD was significant ( $P < 0.05$ ) and positive for fast-growing larvae, but negative for slow-growing larvae on "PI 227687". Larval growth rates were significantly ( $P < 0.05$ ) and positively associated with ECI and ECD for the slow-growing larvae, but the correlations were not significant for the fast-growing larvae. AD was negatively associated with ECI and ECD for the fast-growing larvae, but positively associated for the slow-growing larvae (except for AD versus ECD on "Davis").

Table 3. Correlation matrix between various indices of consumption and utilization of food for the fast- and slow-growing larvae of cabbage looper on 'PI 227687' and 'Davis' soybeans

	'PI 227687'		'Davis'	
	Fast growing	Slow growing	Fast-growing	Slow-growing
CI:GR	-0.35**	-0.97**	0.13	0.64*
CI:ECI	-0.92**	-0.99**	-0.85**	0.35
CI:AD	0.81**	-0.78**	0.72*	0.32
CI:ECD	-0.91**	-0.94**	-0.79**	0.27
GR:ECI	0.53	0.98**	0.41	0.94**
GR:ECD	0.42	0.99**	0.44	0.86**
GR:AD	0.09	0.61	0.04	0.34
ECI:AD	-0.79**	0.76**	-0.67*	0.35
ECI:ECD	0.99**	0.95*	0.96**	0.91*
AD:ECD	-0.86**	0.52	-0.80**	-0.02

\*, \*\* Significant at  $P < 0.05$  and  $P < 0.01$ , respectively. CI = Consumption index, GR = Growth rate, ECI = Efficiency of conversion of ingested food into body matter, AD = Approximate digestibility, and ECD = Efficiency of conversion of digested food into body matter.

#### 4 Discussion

The overall performance of insects is dependent on size, which in turn is correlated with pupal mass (KESTER and SMITH 1984; SLANSKY and SCRIBER 1985). Pupal mass is dependent on the larval maximum mass that a larva attains in the final instar. The later is dependent on the quality of nutrition, and amount of food eaten during the latent feeding period (period between achieving a critical mass in the first instar and the maximum larval mass in the final instar) (OCHIENG-ODERO 1990). Fast-growing and heavy individuals are superior to slow-growing and light-individuals (OCHIENG-ODERO 1990). Slow-growing larvae of *T. ni* developed 10 times slower than the fast-growing larvae, and this can be attributed to their innate differences in consumption and utilization of food.

Ingestion of food/unit of larval mass (consumption index, CI) was significantly lower for the slow-growing larvae, and these differences were greater on the insect-resistant cultivar, "PI 227687" than on the susceptible cultivar, "Davis". Slow-growing larvae were also significantly less efficient in conversion of ingested (ECI) and digested (ECD) food into body matter, and in approximate digestibility (AD). However, the differences in ECD were more pronounced on "PI 227687" than on "Davis", suggesting that slow-growing larvae were also more sensitive to the antifeedant and/or antibiotic effects of isoflavonoids present in "PI 227687" (SHARMA and NORRIS 1991).

Thus, fast-growing larvae were more efficient in utilizing the relatively-resistant cultivar, "PI 227687". In addition to having a rapid generation turn over, the fast-growing larvae in *T. ni* populations represent an evolution of individuals having a greater adaptation to the environment including their capability of utilizing host-plants resistant to insects. Increase in the proportion of fast-growing individuals capable of utilizing diverse sources of food or crop cultivars resistant to insects is one of the mechanisms by which the phytophagous insects may overcome plant resistance, and lead to the evolution of new biotypes. The slow-growing *T. ni* larvae are less efficient in consumption and utilization of food, and they were more sensitive to cultivars resistant to insects.

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#### Zusammenfassung

*Unterschiede in Nahrungsaufnahme und -verwertung bei langsam- und schnellwachsenden Larven von Trichoplusia ni (Hübner) (Lep., Noctuidae)*

Unter Laborbedingungen wurde die Aufnahme und Verwertung von Sojabohnenblättern durch schnell und langsam wachsende Larven von *Trichoplusia ni* untersucht. Schnellwachsende Larven nahmen in bezug auf ihre Körpermasse mehr Nahrung auf und erreichten eine 10mal raschere Gewichtszunahme als langsamwachsende Larven. Bei langsamwachsenden Larven war eine geringere Effizienz der Nahrungsverwertung festzustellen. Diese Unterschiede in der Nahrungsverwertung waren auf der vergleichsweise resistenten Sojabohnensorte „PI 227687“ größer als auf der empfindlichen Sorte „Davis“. Die Ergebnisse werden im Hinblick auf die Züchtung neuer Biotypen von resistenten Wirtspflanzen diskutiert.

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*Authors' addresses:* H. C. SHARMA (for correspondence), Cereals Entomology, International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, A. P. 502 324, India; D. M. NORRIS, Department of Entomology, 237 Russel Labs., University of Wisconsin, Madison, Wisconsin 53706, USA