ECOLOGY, BEHAVIOR AND BIONOMICS

Survivorship, Larval Development and Pupal Weight of *Anticarsia gemmatalis* (Hübner) (Lepidoptera: Noctuidae) Feeding on Potential Leguminous Host Plants

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Neotropical Entomology 33(5):563-567 (2004)

Sobrevivência, Desenvolvimento Larval e Peso Pupal de *Anticarsia gemmatalis* (Hübner) (Lepidoptera: Noctuidae) em Plantas Hospedeiras Potenciais (Leguminosas)

RESUMO - No Brasil, a lagarta-da-soja *Anticarsia gemmatalis* Hübner apresenta várias gerações sobrepostas por ano e parte da população sobrevive em plantas hospedeiras alternativas, principalmente nas regiões mais quentes. O objetivo deste estudo foi avaliar o desenvolvimento e a sobrevivência de lagartas de *A. gemmatalis* em 17 leguminosas cultivadas e não-cultivadas, em laboratório. A sobrevivência das lagartas de *A. gemmatalis* alimentadas com leguminosas de verão variou de 91% em soja a 5% em *C. spectabilis* Roth e mucuna. Nas leguminosas de inverno, a sobrevivência das lagartas variou de 90% em tremoço branco a 25% em ervilhaca comum. Todas as lagartas alimentadas com tremoço amarelo morreram nos primeiros ínstares. Nas leguminosas de verão não-cultivadas (anileiras), 70% das larvas atingiram a fase pupal em *Indigofera suffruticosa* Millsp., e 55% em *I. truxillensis* H.B.K e *I. endecaphyla* Jacq. Considerando-se a sobrevivência, o desenvolvimento das fases imaturas e o peso pupal, as leguminosas mais adequadas para *A. gemmatalis* foram soja, guandu e tremoço branco.

PALAVRAS-CHAVE: Insecta, lagarta-da-soja, planta hospedeira, legume, soja, *Glycine max*

ABSTRACT - In Brazil, the velvetbean caterpillar *Anticarsia gemmatalis* Hübner is multivoltine. Several overlapping generations occur with larvae feeding on alternate host plants in areas of warmer temperatures. In this study, the survivorship and development of *A. gemmatalis* larvae were evaluated on 17 species of cultivated and non-cultivated legumes in laboratory conditions. Larval survivorship on summer legumes varied from 91% on soybean to 5% on showy crotalaria and on velvetbean. On winter legumes, survivorship of *A. gemmatalis* larvae varied from 90% on white lupin to 25% on common vetch. All larvae fed on yellow lupin died during early development. On non-cultivated summer legumes, 70% of the larvae on *Indigofera suffruticosa* Millsp., and 55% on *I. truxillensis* H.B.K. and *I. endecaphylla* Jacq. reached the pupal stage. Based on survivorship, larval development and pupal weight, the most suitable legumes for *A. gemmatalis* were soybean, pigeon pea, and white lupin.

KEY WORDS: Insecta, velvetbean caterpillar, host plant, legume, soybean, *Glycine max*

The velvetbean caterpillar (VBC), *Anticarsia gemmatalis* Hübner, is one of the main pests of soybean (*Glycine max* [L.] Merrill) in the western hemisphere (Turnipseed & Kogan 1976), in particular in the Neotropical Region. In Brazil, 90% of the total insecticide application on this crop is used to control the VBC and stink bugs (Moscardi 1993).

Host plants of the VBC are in general, legumes. Armstrong *et al.* (1990) refer to VBC on cowpea and Gregory *et al.* (1991) report the VBC on legumes of the genus *Tephrosia*. It can be found on other plants, such as cotton, *Gossypium hirsutum* L., coffee weed, *Cassia obtusifolia* L., and *Polygonum punctatum* Elliot (Buschman *et al*. 1977). According to MacKenzie *et al*. (1985) the ability of *A. gemmatalis* to survive unfavorable winter conditions may be threatened by the lack of suitable host plants during the beginning and the end of the season.

In Brazil, *A. gemmatalis* is multivoltine and part of the population survives during mild winters on alternative host plants, in particular above the Tropic of Capricorn, where warmer temperature occurs. In the Londrina area (latitude 23° 11' S, longitude 51° 11' W) larvae may be found feeding during most of the year on hairy indigo, *Indigofera hirsuta* L. and

perennial soybean, *Glycine* sp. (A.R. Panizzi, unpublished). The availability of suitable host plants during the entire year is suspected to be a major factor to increase the population of this pest on soybean.

Studies in the laboratory on the development and reproductive performance of the velvetbean caterpillar on alternative food plants have been conducted in the USA (Slansky 1989, Waters & Barfield 1989). They are considered important to suggest which host plants may be playing a major role in the VBC ecology in the field (Slansky 1989).

In Brazil, despite the importance of *A. gemmatalis* as a key pest of soybean, there are no studies dedicated to evaluate the impact of alternative host plants on its biology. Therefore, we report the effect of 17 different species of cultivated and non-cultivated legumes, on the survivorship, larval development, and pupal weight of this pest.

Material and Methods

Three studies were conducted in the laboratory in a completely randomized design. The suitability of summer and winter cultivated and non-cultivated legumes, commonly found in the Londrina area, in supporting the development of *A. gemmatalis* was evaluated. The suitability of the plants was assessed by measuring survivorship, larval developmental time, and pupae weight. Leaf consumption and fresh body weight gain of 5th-instar larvae were also evaluated on selected summer legume hosts.

Cultivated Summer Legumes. In the first study, we tested five different legumes which are usually cultivated during summer: pigeon pea (*Cajanus cajan* L.), cowpea [*Vigna unguiculata* (L.) Walp.], sun hemp crotalaria (*Crotalaria juncea* L.), showy crotalaria (*Crotalaria spectabilis* Roth), and velvetbean [*Stilozobium. aterrimum* (*Mucuna aterrima*) Piper & Tracy].

Replications (n = 40) consisted of using one larva of the first instar, selected from the rearing stock previously fed using artificial diet. Single larvae were placed into a plastic box (11.5 x 11.5 x 3.5 cm) covered with a lid, and kept in an environmental chamber at 25 ± 2ºC, 65 ± 10% RH, and 12 hL photo phase. Daily observations were made, when food was changed. Food consisted of leaves obtained from potted plants cultivated in the greenhouse, offered to the larvae *ad libitum*. At pupation, fresh weight of pupae was recorded.

An additional study was conducted, similar to the previous one, using the following legume plants: sun hemp crotalaria, pigeon pea, velvetbean, and soybean. In this study larvae (n = 20) were individualized in plastic boxes, fed with their respective food leaves. At the first day of the 5th instar, each larva received leaves previously weighted, until it reached the last day of the 5th instar. Fresh body weight (mg) of larvae was recorded at day 1, and at the last day of the 5th instar. The leftover food was taken daily, dried in oven, and the dry weight recorded. To obtain the dry weight of leaves offered to the larvae, fresh weight was corrected to dry weight using a conversion factor, obtained from five check leaves/day/food, kept in similar conditions as to the leaves used to obtain the fresh weight at the beginning and at the end of the feeding period.

Cultivated Winter Legumes. In the second study, eight species of legumes cultivated during winter were selected and tested in a similar way as previously described for experiment 1: white lupin [*Lupinus albus* (L.)], yellow lupin [*L. luteus* (L.)], blue lupin [*Lupinus angustifolius* (L.)], chickling vetch (*Lathyrus sativus* L.), pea (*P. sativum* cv. 'Triofin'), hairy pea (*P. sativum*), vetch (*Vicia sativa* L. cv. 'Poneka'), and common vetch (*V. angustifolia* L.). In this experiment 50 larvae were used for each plant.

Non-Cultivated Summer Legumes. In the third study, three non-cultivated legumes, commonly found nearby soybean fields, were used, each replicated 20 times: *Indigofera suffruticosa* Millsp., *I. truxillensis* H.B.K, and *I. endecaphylla* Jacq.

In the three experiments, soybean was included as the standard food for comparison. Larval + pupal survivorship of individuals fed on each food was calculated as a percentage of those reaching adulthood. Larval and pupal developmental time (days), pupae fresh weight (mg), dry weight of food ingested (mg), and fresh body weight gain (mg) of 5th-instar larvae were calculated to mean ± SE. Data were analyzed statistically using ANOVA, and means were compared using the Tukey test ($P \leq 0.05$).

Results

Cultivated Summer Legumes. Suitability of different legumes to support larval development of *A. gemmatalis* fed on summer legumes was variable. On the known preferred host, soybean, survivorship was >90%; intermediate values (slightly over 70%) were observed on pigeon pea and cowpea. Survivorship values were drastically smaller on sun hemp crotalaria (≈30%), and on showy crotalaria and velvetbean (6%) (Table 1).

Food source also affected larval and pupal development with larva and pupa developing much faster on soybean and pigeon pea compared to cowpea and sun hemp crotalaria, if we consider only those plants on which more than 30% survivorship was obtained (Table 1). Pupae were heavier on soybean (≈223 mg) than on the remaining food plants, on which pupal weight was less than 196 mg.

Survivorship of 5th-instar larvae of *A. gemmatalis* on most of the summer legumes studied confirmed that they are usually suitable foods, except sun hemp crotalaria, on which survivorship was almost three times greater compared to the former test when this was measured during the entire larval + pupal period; this suggests that most mortality of VBC larvae occurs on earlier instars on this food (Table 2). Dry weight of ingested food by 5th-instar larvae was similar on the four legumes tested, but fresh body weight gain was greater on soybean (>180 mg) than on pigeon pea or sun hemp crotalaria (<82 mg) (Table 2).

Cultivated Winter Legumes. When *A. gemmatalis* larvae were fed with legumes cultivated during winter, survivorship on white lupin (*L. albus*), and on vetch (*V. sativa* cv. Poneka) was similar to that on the preferred food plant used as check, soybean (Table 3). On pea (*P. sativum* cv. 'Triofin'), on hairy pea, and on chickling vetch (*L. sativus*), larvae survivorship

Table 1. Survivorship (%), larval developmental time, and pupal weight (mean ± SE) of *A. gemmatalis* fed on different summer legumes, and on soybean, in the laboratory (25 ± 2ºC, 65 ± 10% and 12 hL).

Legume species	Survivorship[1]	Developmental time (days)			Pupal fresh weight (mg)
		Larva	Pupa	Larva-adult	
Cowpea	72	24.2 ± 0.54 a	10.6 ± 0.24 a	34.8 ± 0.81 a	171.4 ± 14.05 b
C. juncea	31	19.8 ± 1.03 b	10.5 ± 0.29 ab	28.7 ± 1.70 b	175.7 ± 17,48 ab
Pigeonpea	75	14.7 ± 0.45 c	8.8 ± 0.26 b	24.4 ± 0.74 c	195.7 ± 11.74 ab
Soybean	91	13.5 ± 0.28 c	9.2 ± 0.34 b	22.8 ± 0.61 c	222.8 ± 5.89 a
F-value	--	107.686	5.180	44.174	5.364
Prob. F	--	<0.001	0.004	<0.001	0.003

[1]Initial number of larvae in each treatment = 40. Survivorship value of larvae feeding on *C. spectabilis* and on velvetbean = 6%
Means followed by the same letter in each column do not differ significantly using the Tukey test (P < 0.05).

was intermediate. On blue lupin (*L. angustifolius*), and on common vetch (*V. angustifolia*), survivorship was low (Table 3). All larvae fed on yellow lupin (*L. luteus*) died during the first two instars.

Larval developmental time was significantly longer (≈24 days) on blue lupin (*L. angustifolius*) than on the remaining hosts (range of ≈13 to 18 days), but no differences were observed on the time required for pupal development (Table 3). The arrested larval development of *A. gemmatalis* on blue lupin resulted in a prolonged period of development from larva to adult on this plant, which was 6-9 days longer than that on the remaining food plants.

Pupal weight ranged from 128 to 264 mg (Table 3). Heavier pupae were produced on soybean and white lupin (*L. albus*), while blue lupin resulted in the development of lighter pupae.

Non-Cultivated Summer Legumes. The development of *A. gemmatalis* larvae on non-cultivated legumes was also greatly variable. On the several indigo species tested, larval survivorship ranged from 55% to 70%, lower than that obtained on soybean (85%). Among the three indigo species, *I. suffruticosa* was the most suitable to support larval development of *A. gemmatalis* (Table 4).

Larval developmental time was similar among the three indigo species and soybean, but pupal development was delayed when larvae fed on *I. endecaphylla* (Table 4). This prolonged pupal development explains the longer larval-pupal development obtained on *I. endecaphylla*, which as approximately three days longer than that obtained on *I suffruticosa* and on soybean. When considered together, i.e., larval and pupal developmental time, larvae fed on *I. endecaphylla* and on *I. truxillensis* took longer than those on *I. suffruticosa* and on soybean (Table 4). No differences in fresh weight of pupae were observed on the four foods tested (Table 4).

Discussion

The results indicated that the polyphagous velvetbean caterpillar, *A. gemmatalis*, shows a great variability on its performance according to the type of food ingested. This variability may be pronounced even when it is compared between legumes within the same genus.The variation in survivorship of larvae fed on different species of crotalaria (25% - see Table 1), lupin (51% - Table 3), and vetch (65% - Table 3) illustrates this fact. Certainly, physical and/or

Table 2. Survivorship (%), leaf consumption, and fresh body weight gain (mean ± SE) of 5th-instar larvae of *A. gemmatalis* fed on different summer legumes, and on soybean, in the laboratory (25 ± 2ºC, 65 ± 10% and 12 hL).

Legume species	Survivorship[1]	Dry weight of ingested leaf (mg)	Fresh body weight gain (mg)
Soybean	87	286.8 ± 18.08	187.3 ± 14.70 a
Velvetbean	67	278.7 ± 36.21	132.4 ± 24.07 ab
Pigeonpea	67	315.3 ± 35.34	81.8 ± 00.00 b
C. juncea	83	340.5 ± 43.21	73.6 ± 11.59 b
F-value	--	0.805	7.875
Prob. F	--	0.503	0.001

[1]Initial number of larvae in each treatment = 20
Means followed by the same letter in each column do not differ significantly using the Tukey test (P < 0.05).

Table 3. Survivorship (%), larval developmental time, and pupal weight (mean ± SE) of *A. gemmatalis* fed on different winter cultivated legumes, and on soybean, in the laboratory (25 ± 2ºC, 65 ± 10% and 12 hL).

Legume species	Survivorship[1]	Development time (days)			Pupal fresh weight (mg)
		Larva	Pupa	Larva-adult	
Soybean	86.3	14.1 ± 0.17 c	10.3 ± 0.20	24.3 ± 0.33 c	263.7 ± 5.75 a
L. albus	90.8	13.6 ± 0.10 c	10.3 ± 0.15	24.0 ± 0.21 c	253.0 ± 5.57 ab
V. angustifolia	25.0	13.7 ± 0.40 c	10.0 ± 0.49	23.9 ± 0.86 c	215.4 ± 15.0 bc
V. sativa ´Poneka´	90.7	15.0 ± 0.18 c	9.9 ± 0.22	24.9 ± 0.34 c	196.5 ± 5.33 c
P. sativum ´Triofin´	64.7	17.3 ± 0.40 b	9.9 ± 0.41	26.4 ± 0.71 c	193.7 ± 7.24 c
P. sativum (hairy)	74.4	13.8 ± 0.20 c	10.2 ± 0.26	24.3 ± 0.37 c	193.3 ± 6.90 c
L. sativus	74.5	18.3 ± 0.23 b	10.5 ± 0.20	28.7 ± 0.28 b	191.3 ± 5.83 c
L. angustifolius	40.0	23.5 ± 0.43 a	10.2 ± 0.25	34.6 ± 0.87 a	128.3 ± 8.56 d
F-value	--	145.630	0.859	46.890	33.490
Prob. F	--	<0.001	0.54	<0.001	<0.001

[1]Initial number of larvae in each treatment = 50
Means followed by the same letter in each column do not differ significantly using the Tukey test (P < 0.05).

chemical attributes of these "similar" hosts are affecting larval development in different ways and should be elucidated.

The delayed developmental time of larvae and pupae on cowpea was also observed by Waters & Barfield (1989) who reported a greater number of instars for larvae fed on this plant. Additional data showing lower pupal weight on cowpea demonstrate that this is only an intermediate suitable host. The same can be said for sun hemp crotalaria (*C. juncea*), although survivorship of larvae was much lower on this plant. However, showy crotalaria (*C. spectabilis*) was a poor host, which is in agreement with the data reported by Waters & Barfield (1989).

Most VBC larvae reached adulthood on pigeon pea, despite the lower fresh body weight gain of 5th-instar larvae on this food. Because this legume is abundant in most areas of soybean cultivation, such as in the north of Paraná state, and because it remains with green leaves during most of the year, it should be considered an important food source for the VBC. *A. gemmatalis* has been reported as an important pest of this legume in Puerto Rico (Armstrong *et al*. 1990).

Buschman *et al.* (1977) reported that *A. gemmatalis* was collected in great numbers in hairy indigo (*I. hirsuta*) during the fall in Florida. Based on several parameters measured, it was considered as good as soybean (Conti & Waddill 1982) and a suitable host for the VBC larvae (Waters & Barfield 1989). Although, we did not test this species of indigo in the laboratory, these reports are in agreement with our field observations, indicating the presence of VBC larvae on this host in the Londrina area. From the other indigo legumes tested, *I. suffruticosa*, *I. truxillensis*, and *I. endecaphylla*, the second one presented the best results, in general, comparable to those observed on soybean. These non-cultivated legumes are abundant along roadsides and fields, being available during most of the year in the Londrina area. Therefore, we suspect they are playing a major role in hosting VBC populations, when soybean is not present in the field.

Table 4. Survivorship (%), larval developmental time, and pupal weight (mean ± SE) of *A. gemmatalis* feeding on different summer non-cultivated legumes, and on soybean, in the laboratory (25 ± 2ºC, 65 ± 10% and 12 hL).

Legume species	Survivorship[1]	Developmental time (days)			Pupal fresh weight (mg)
		Larva	Pupa	Larva-adult	
I. endecaphylla	55	12.1 ± 0.10	8.0 ± 0.36 a	20.0 ± 0.36 a	185.2 ± 5.46
I. truxillensis	55	11.6 ± 0.26	6.3 ± 0.21 b	19.0 ± 0.91 a	177.8 ± 9.12
I. suffruticosa	70	11.4 ± 0.18	5.9 ± 0.14 b	17.0 ± 0.22 b	183.9 ± 7.35
Soybean	85	11.5 ± 0.17	5.9 ± 0.80 b	17.2 ± 0.18 b	195.2 ± 6.94
F-value	--	1.639	19.370	10.176	0.943
Prob. F	--	0.189	<0.001	<0.001	0.432

[1] Initial number of larvae in each treatment = 20
Means followed by the same letter in each column do not differ significantly using the Tukey test (P < 0.05).

The low survivorship of *A. gemmatalis* larvae on the common vetch (*V. angustifolia*) is in agreement with results obtained by Slansky (1989) in Florida. This and other hosts of low nutritional value may prevent the rapid development of migratory populations, as suggested by Moscardi *et al*. (1981a). However, the greater survivorship of VBC on other legumes cultivated during winter should be important to keep individuals able to reproduce year round. This might be possible considering that the mean temperature during winter in the Londrina area is 17.2°C (J.R.B. Farias, pers. comm.), and this temperature allows VBC to reproduce, despite reduced survivorship below 18°C (Moscardi *et al*. 1981b). Considering that soybean is moving northward into the central-west and northeast of Brazil, the warmer temperatures of these regions should allow the VBC to reproduce the entire year, either on wild non-cultivated or cultivated legumes.

A. gemmatalis is known to migrate through eastern and central United States during summer and fall, and to overwinter in south Florida (Herzog & Todd 1980, Pashley & Johnson 1986). In Brazil, a study demonstrated that during summer the population peak of VBC on soybean moves to later periods, as its goes southward to greater latitudes (Corrêa *et al.* 1977). This suggests that the VBC migrates from the northern to the southern areas; however, this has not been fully elucidated. In addition, it is not known whether the VBC population returns northward to overwinter or not.

In conclusion, based on survivorship and larval/pupal developmental time, in addition to soybean, the cultivated legumes pigeon pea, which is available during the spring/summer/fall, and white lupin, available during winter, were considered the most suitable food plants for *A. gemmatalis* in the laboratory. Among the non-cultivated legumes, the indigo species, in particular *I. suffruticosa*, showed to be adequate foods.

Acknowledgments

We thank Flávio Moscardi, Clara B. Hoffmann-Campo and an anonymous reviewer for critical reading of the manuscript. This paper has been approved for publication by the Embrapa Soja Publication Committee as manuscript number 22/2003.

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Received 30/09/03. Accepted 01/06/04.