Population Dynamics and Susceptibility to insecticides of variegated cutworm attacking tomatoes in Southwestern Ontario

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SUMMARY

The variegated cutworm, *Peridroma saucia* (Hübner) (VCW) is a general feeder which attacks many agricultural crops. In southwestern Ontario, the larvae sporadically damage vegetable and field crops, especially tomatoes in mid-summer. Pyrethroid insecticides have provided most effective control. However, recent anecdotal reports of less than effective VCW control have led to the suggestion that it has developed resistance to these insecticides. The objectives of this study were to: 1) acquire information on the biology of VCW on tomatoes in southwestern Ontario; 2) assess the toxicity of currently registered and novel control products to different VCW larval instars; and, 3) determine whether VCW has developed resistance to presently registered control products.

In preparation for the study comprehensive literature reviews comprising several hundred reports published from 1886-2006 were compiled and have been included in this report.

In summer 2006, VCW biology was studied in selected tomato fields in Norfolk and Essex counties using black light and pheromone traps which were frequently checked from late June through September. In Norfolk County there were 2 peaks of adult activity in July and August while in Essex County there were 3 peaks during July, August and September. VCW is considered to be migratory and the July adult peak presumably comprised adults moving from the south into Ontario. The August peak in both counties signaled completion of the 1st generation arising from the migrants. The 3rd peak, which occurred only in Essex County, signaled completion of a 2nd generation of VCW development under the warmer climatic conditions in that area.
A laboratory VCW culture was established at the University of Guelph in late Summer 2006, from 5th instar larvae collected from tomato fields in both counties. Direct contact toxicity bioassays were done in the Toxicology Laboratory at the Southern Crop Protection and Food Research Centre, AAFC in London, Ontario. Of the 4 insecticides commonly used for cutworm control, lambda-cyhalothrin was most toxic to 3rd-4th instar larvae > permethrin > chlorpyrifos > methomyl. Chlorantraniliprole was most toxic of the novel chemicals > spinosad > metaflumizone. Spinosad and metaflumizone, which act primarily as stomach poisons, were less toxic by direct contact. In tests with permethrin, 2nd instar larvae were most susceptible > 3rd-4th > 5th instar. Comparison of results with data published in 1977 showed that VCW had developed low level resistance to methomyl but not to chlorpyrifos or permethrin. Results of the study showed that pyrethroid insecticides will be effective so long as stage of larval development and climatic conditions are considered, and insecticides are applied in a manner resulting in the most effective penetration of the plant canopy possible.

INTRODUCTION

The variegated cutworm, *Peridroma saucia* (Hübner) (VCW) is a generalist feeder on vegetable crops, cereals, ornamentals, fruit and forage crops. Rings et al. (1976) compiled a comprehensive world-wide bibliography of published VCW research from 1886-1976 (Appendix I) and Drew (2006) reviewed literature published between 1977-2006 (Appendix II). In southwestern Ontario, the adults are migratory and are present throughout the growing season (McClanahan and Elliot, 1976). The larvae sporadically cause damage to vegetable and field crops in the early part of the growing season but usually are a greater problem in mid-summer, especially in fields of tomatoes (Harris et al., 1977). While the organochlorine
insecticides provided effective VCW control (Harris et al., 1961) organophosphorus and carbamate insecticides were less so, with effectiveness being very dependant on stage of larval development and method of insecticide application (Harris and Svee, 1968; Harris and Kinoshita, 1977; Harris et al., 1977). Pyrethroid insecticides provided effective VCW control (Harris et al., 1977). Insecticides currently recommended for cutworm control in Ontario are carbaryl (Sevin XLR), methomyl (Lannate LV), acephate (Orthene 75SP), with the pyrethroids - permethrin (Pounce EC), and lambda-cyhalothrin (Matador 120EC), being considered most effective. However, recently anecdotal reports of less than adequate VCW control have lead to the suggestion that VCW has developed resistance to pyrethroids.

The objectives of this project were to:

1. Acquire much needed information about VCW biology on tomatoes in southern Ontario.

2. Assess the effectiveness of currently registered and novel control products on different VCW larval instars.

3. Determine whether VCW is resistant to presently registered control products.

MATERIALS AND METHODS

Literature Review

Rings et al. (1976) provided valuable information on VCW articles published between 1880 and 1976. With the assistance of Dorothy Drew, librarian at AAFC – London, a further review covering the period 1977-2006 was prepared.
**Biology**

In Summer 2006, 6 bucket-style pheromone traps (Muti-Pher®) (2 traps/field) baited with Trece® Pherocon Cap VGC – variegated cutworm pheromone lures (Distributions Solida Inc., QC) were operated from late June to late September at 3 tomato farms in Norfolk County. Two pheromone traps were placed in each tomato field. Traps were checked twice weekly from 26 June to 14 September and numbers of adult males captured were recorded. Pheromone lures were replaced mid-July in order to maintain effectiveness. A Hercon® Vaportape II (10% dichlorvos), insecticide strip was placed in each pheromone trap at the beginning of the study to kill adults and prevent escape. One Vaportape installed at the beginning of the study was sufficient to last through the 14 weeks of trapping.

Four pheromone traps (2 traps/field) were operated from early July to late September at 2 tomato fields in Essex County. Traps were checked regularly from 11 June to 19 September and numbers of adult males captured were recorded. Two traps (1 at each location) did not operate correctly, therefore trap catch data were generated from only 2 traps in Essex County.

**Insecticide Effectiveness**

*Insect Culture*

The laboratory colony was started in the Summer of 2006 from VCW larvae collected from tomato fields in Norfolk and Essex Counties. Larvae were reared in plastic containers (34 x 25 x 13cm) with screened (10 x 15 cm) lids filled with 5 cm of sterilized sandy loam soil (Fig. 1a). Chinese cabbage was used as a food source (Fig. 1b). Larvae were fed 3 times a week (Monday, Wednesday and Friday) and dry, rotten or moldy materials were removed from cages. Pupae were collected and placed in adult cages, made of 11 L ice cream buckets
with a 15 x 10 cm screened opening on the side (Fig. 1c). Red Gatorade® and deionized water were used as food and moisture sources (Fig. 1c). A piece of red tissue paper (20 x 20 cm) was crumpled and placed in the container for use as an oviposition site. Pieces of red tissue paper with egg masses attached were placed on 9 cm diam filter paper in 10 cm Petri dishes with a commercial VCW diet (Southland Products Inc., Arkansas) cube (0.5 cm³). Rearing cages were kept in environmental chambers set at 23 ± 2ºC, 60-70% relative humidity (RH) and 16:8 light:dark (L:D) regime.

Figure 1. Variegated cutworm larval rearing cages (a); food materials (b); and an adult Cage (c).

**Biological Assays**

Direct contact toxicity of technical grade (> 95% purity) permethrin, chlorpyrifos, methomyl, chlorantraniliprole, lambda-cyhalothrin, spinosad and metaflumizone to VCW larvae was determined using a Potter spray tower (PST) (Potter, 1959) and the procedure described by Harris et al. (1977). Primary screening tests were done with 2-4 concentrations of the insecticides dissolved in 19:1 acetone:olive oil. Controls treated with the solvent alone were included with each insecticide bioassay. Two groups of 10, 3rd-4th instar larvae were tested at each insecticide concentration. Each bioassay was repeated 3 times i.e., 60 larvae per concentration. Larvae were transferred with a fine paint brush to a clean 10 cm glass
Petri dish lined with 9 cm diam filter paper and were placed in the PST (Fig. 2a). Five ml of the desired concentration of each insecticide were then applied via the PST (Fig. 2b). Treated VCW were placed in waxed paper Dixie® cups filled with 1 cm sifted sandy loam and 2 commercial VCW diet cubes (90.5 cm³) as a food source (Fig. 2c). Cups were then covered with a 10 cm glass Petri dishes and placed in a holding room at 25 ± 1°C and 16:8 L:D immediately after treatment. Mortality counts were made after 48 h. Larvae were considered dead if unable to crawl. Second and 5th instar larvae also were tested to determine the susceptibility of different VCW larval stages to pyrethroids. Correction for natural mortality (< 10%) were made using Abbott’s formula (Abbott, 1925).

Figure 2. Petri dishes containing 10 variegated cutworm (VCW) larvae (a), preparation for application of technical grade insecticide using a spray tower (b); following insecticide exposure VCW larvae were placed in Dixie cups, containing sifted sandy loam and diet cubes following treatments (c).

RESULTS

Literature Review

Copies of literature reviews prepared by Rings et al. (1976) and Drew (2006) covering the period 1880-2006 are attached (Appendices I and II).
Biology

In 2006, there were 2 peaks of adult activity in Norfolk County in July and August. Populations dropped to low levels in mid-August remaining that way until the study was terminated in mid-September (Fig. 3).

In 2006, there were 3 peaks of adult activity in Essex County in July (primary), and August (secondary) and September (tertiary) (Fig. 3). As was the case in Norfolk County, the July peak likely represents migrating adults, while the August peak represents the 1st generation arising from the migratory individuals. McClanahan and Elliott (1976) determined a 3rd peak in September and we made similar observations. The 3rd peak of adult activity suggests that the warmer climatic conditions in Essex versus Norfolk County support a 2nd generation of VCW development.

Insecticide Effectiveness

Of the 4 insecticides commonly used for cutworm control, lambda-cyhalothrin was most toxic to 3-4th instar VCW > permethrin > chlorpyrifos > methomyl. Chlorantraniliprole was the most toxic of all the insecticides tested; spinosad and metaflumizone were the least toxic (Table 1). In tests establishing the susceptibility of different larval stages to permethrin, 2nd instar larvae were most susceptible > 3rd-4th > 5th instar (Table 2).
Figure 3. Mean numbers of adult male variegated cutworm (VCW) captured in pheromone traps in tomato fields in Norfolk and Essex Counties during Summer, 2006.
Table 1. Direct contact toxicity of 7 insecticides (technical grade) to 3rd-4th instar variegated cutworm (VCW) larvae from the field collected southwestern Ontario population established in culture during 2006.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Average corrected % VCW mortality at insecticide solution indicated</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.0001</td>
</tr>
<tr>
<td>Lambda-cyhalothrin</td>
<td></td>
</tr>
<tr>
<td>Permethrin</td>
<td></td>
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<tr>
<td>Chlorpyrifos</td>
<td></td>
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<tr>
<td>Methomyl</td>
<td></td>
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<tr>
<td>Chlorantraniliprole</td>
<td></td>
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<tr>
<td>Spinosad</td>
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<td>Metaflumizone</td>
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</tbody>
</table>

DISCUSSION AND CONCLUSIONS

One objective of this study was to obtain further information on the biology of VCW in southwestern Ontario. In 2006, the small July adult peak noted in Norfolk County likely represented migratory adults, while that in August comprised the 1st generation arising from those adults (Fig. 3). McClanahan and Elliot (1976) reported that VCW had 3 peaks in Essex County in July, August and September suggesting that it had 2 generations in that area. Similar results were obtained in 2006 (Fig. 3). It appears that the warmer climatic conditions in Essex as compared to Norfolk allow 2nd generation VCW to complete development.

The 2 pyrethroid insecticides, lambda-cyhalothrin and permethrin were the most toxic of the insecticides commonly used for cutworm control. Of the 3 novel chemicals tested, chlorantraniliprole was at least as toxic as lambda-cyhalothrin (Table 1). Spinosad and metaflumizone were less toxic by direct contact, however it is known that these insecticides act primarily as stomach poisons, thus these results may not fully reflect their potential for VCW control. Results obtained with methomyl, chlorpyrifos and permethrin were compared with those obtained under identical bioassay conditions by Harris et al. (1977) (Table 2).
VCW appears to have developed a relatively low level of resistance to methomyl, possibly due to exposure of the migrant VCW population to use of that chemical on numerous host crops in North America. Results obtained with chlorpyrifos in the 2 years were similar with no indication of significant resistance development to that chemical.

**TABLE 2.** Comparison of the direct contact toxicity of technical grade methomyl, chlorpyrifos and permethrin to 3rd-4th instar variegated cutworm under identical bioassay conditions, 1977 and 2007.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Year</th>
<th>Average corrected % mortality at % insecticide solution indicated</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td>Methomyl</td>
<td>1977*</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>0</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>1977*</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>2</td>
</tr>
<tr>
<td>Permethrin</td>
<td>1977*</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>2007</td>
<td>7</td>
</tr>
</tbody>
</table>


While it has been suggested that unsatisfactory VCW control with permethrin on tomatoes could be due to resistance, results obtained with the 2006 Ontario VCW strain were identical to those reported 30 years earlier (Harris et al., 1977), i.e., there was no evidence of resistance development. An explanation for less than acceptable VCW control with permethrin can be found in past research which has shown that several factors influence the effectiveness of insecticides applied for VCW control including stage of larval development, climatic conditions and application method. Stage of larval development is very important. Harris et al. (1977) showed that, while 1st instar VCW were very susceptible, 3rd and 5th instar larvae were 2.9x and 3.7x more tolerant to permethrin, respectively and similar results were obtained in this study. Harris and Kinoshita (1977) demonstrated that, like DDT, pyrethroid toxicity can be negatively correlated with temperature – permethrin was 7.4x
more toxic to 3rd instar VCW at 15° as compared to 32°C. Finally, application method has a major role. For example, VCW spends the larval stage on, or very close to, the soil surface hidden under dense foliage. While soil surface applications with permethrin were effective, foliar applications were less so (Harris and Svec, 1968; Harris et al., 1977).

Results of this study show that the pyrethroid insecticides remain highly toxic to VCW populations found in southern Ontario and that there is no evidence of resistance to permethrin. Lack of insecticide effectiveness in the field is undoubtedly due to limited mobility of the cutworms once they become established under the plant canopy. To achieve adequate control, insecticides should be applied when early instar larvae are present, under moderate to cool climatic conditions, in a manner resulting in the most effective penetration of the plant canopy possible.

ACKNOWLEDGEMENTS

The authors would like to thank the grower cooperators in Norfolk and Essex Counties who graciously allowed us to place pheromone traps and collect variegated cutworm larvae in their fields. We also thank Jay Whistlecraft and Dr. Jeff Tolman for advice, and use of facilities and equipment at AAFC-London; and Justin Glatt for technical assistance. Funding for this research was provided through an Agricultural Adaptation Council CORD IV Grant to University of Guelph via the Fresh Vegetable Growers of Ontario.
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Harris, C.R. and H.J. Svec. 1968. Toxicological studies on cutworms IV. Laboratory investigations on the toxicity of insecticides to the variegated cutworm, with special reference to method of application on insecticidal activity. J. Econ. Entomol. 61: 970-973.
APPENDIX I


Roy W. Rings, Beth A. Johnson and Fred. J. Arnold

Ohio Agricultural Research and Development Center, Wooster, Ohio
Research Circular 219 – June 1976

2. Amate, J., P. Barranco, and T. Cabello. 2000. Biology of noctuids pest under controlled conditions (Lepidoptera: Noctuidae); Biologia en condiciones controladas de especies de noctuidos plaga (Lepidoptera: Noctuidae), no. 2:193-201. Abstract: La biologia de diversas especies de noctuidos plaga de Espana ha sido estudiada en condiciones ambientales controladas (25+-0,5 grados C; 80+-10% HR; 18:6 horas de luz:obscuridad y alimentacion con dieta artificial). Se estudian aspectos relacionados con el ciclo de vida de las siguientes especies Agrostis ipsilon (Hufnagel, 1766), Autographa gamma (Linnaeus, 1758), Helicoverpa armigera (Hubner, 1808), Peridroma saucia (Hubner, 1808), Spodoptera littoralis (Boisduval, 1833) y Trichoplusia ni (Hubner, 1803). Se constata que la duracion del estado de huevo fue proxima a cuatro dias para las especies estudiadas a excepcion de Peridroma saucia, que presento un dia de retraso respecto al resto. El estado de larva presenta diferencias entre especies y solo se vio influenciada por el sexo en las especies Spodoptera littoralis. El estado de pupa tiene una duracion diferente para cada especie y se haya influenciada por el sexo, siendo siempre superior en machos. La longevidad de adultos entre especies, fue similar para hembras, mientras que en machos existieron diferencias importantes. Por ultimo, la fecundidad vario considerablemente entre especies, siendo la mayor la presentada por Spodoptera littoralis con mas de 3000 huevos ovipositados por hembra.

3. Armstrong, J. L., L. A. Porteous, and N. D. Wood. The cutworm Peridroma saucia (Lepidoptera: Noctuidae) supports growth and transport of pBR322-bearing bacteria. *Applied and Environmental Microbiology* 55[9], 2200-2205. 1989. Abstract: Variegated cutworms were exposed to bean plants in microcosms sprayed with pBR322-carrying strains of Enterobacter cloacae, Klebsiella planticola, and Erwinia herbicola. The three bacterial species exhibited differential survival on leaves, in soil, and in guts and fecal pellets (frass) of the insects. High numbers of Enterobacter cloacae(pBR322) were detected in all samples, while the other species were unable to establish residence in the insect. To assess the impact of this colonization on site-to-site transport of microorganisms, larvae were fed plants that had been sprayed with the bacteria and then were transferred to uninoculated plants. Cutworms were efficient carriers of Enterobacter cloacae(pBR322), as indicated by its rapid appearance on uninoculated leaves and continued persistence in the insects for 3 days after transfer. Few Erwinia herbicola(pBR322) and K. planticola(pBR322) were
obtained from larvae after transfer, although up to 10(3) CFU/g were detected in soil and on plants. Differences in bacterial survival and growth were confirmed by incubating frass overnight and observing the change in population numbers. The proportion of total samples showing at least a 25-fold increase during incubation was 68% for Enterobacter cloacae(pBR322), 39% for K. planticola(pBR322), and 0% for Erwinia herbicola(pBR322). Our results emphasize the role that cutworms and possibly other insects have in persistence and growth of microorganisms in the environment.


5. Arnason, J. T., M. B. Isman, B. J. Philogene, and T. G. Waddell. Mode of action of the sesquiterpene lactone, tenulin, from Helenuim amarum against herbivorous insects. Journal of Natural Products 50[4], 690-695. 1987. Abstract: Tenulin [1], a sesquiterpene lactone from Helenuim amarum, is a potent antifeedant to the European corn borer Ostrinia nubilalis. At 3 mumol/g in artificial diets, 1 reduced growth and delayed larval development of O. nubilalis and the variegated cutworm Peridroma saucia larvae. An especially pronounced carry-over effect in O. nubilalis was substantial reduction in fecundity of adult moths resulting from treated larvae. The LD50 (lethal dose for 50% mortality) of 1 by injection in the migratory grasshopper Melanoplus sanguinipes was 0.88 mumol/insect. Toxicity in M. sanguinipes was antagonized by co-administration of cysteine, suggesting that the cyclopentenone group of tenulin undergoes Michael addition of biological nucleophiles in vivo. This mechanism was partially confirmed by the finding that only tenulin analogues capable of acting as electrophile acceptors had significant antifeedant activity.

6. Ashelford, K. E., M. A. Learner, and J. C. Fry. 2001. Gene Transfer and Plasmid Instability Within Pilot-Scale Sewage Filter Beds and the Invertebrates That Live in Them. Fems Microbiology Ecology 35, no. 2:197-205. Abstract: The environmental plasmid pQKH6 was transferred conjugatively between strains of Pseudomonas putida at mean frequencies of up to 8.4x 10(-4) within pilot-scale sewage filter beds. This frequency was 10-fold higher than that reported previously for this environment and was probably due to seasonal temperature changes. Many (45%) of the plasmids isolated subsequently from the filter beds had restriction fragment length polymorphism (RFLP) profiles that differed from that expected for pQKH6. RFLP analysis revealed structural rearrangements occurring within a practically restriction-site-rich region of the plasmid. Although no evidence was obtained showing the indigenous invertebrate populations within the filter beds to influence the rate of gene transfer, pQKH6 was transferred with frequencies of up to 1.6 x 10(-2) within the guts of the filter-bed-dwelling Sylvicola fenestralis larvae during laboratory experiments. This transfer was strongly influenced by donor to recipient ratios.
Laboratory experiments also showed that Serratia fonticola survived better within invertebrate guts than P. putida. This evidence, along with experiments showing that S. fonticola could participate in pQKH6 transfer within filter-bed bio film, identify this bacterium as a better model than P. putida for examining the effect of invertebrates on gene transfer. (C) 2001 Federation of European Microbiological Societies. Published by Elsevier Science B.V. All rights reserved.

7. Balevski, A., N. Genchev, A. Markov, and G. Georgiev. 1974. Chemical control of Noctuid larvae. Rastitelna Zashchita 22, no. 10:26-30. Abstract: Agrotis segetum (Schiff.) and Peridroma saucia Hb. are important pests of crops in Bulgaria. Laboratory and field experiments on the control of the former were conducted at agricultural stations at Kostinbrod and Sofia in which larvae in the fourth, fifth and sixth instars were exposed to various insecticides, used singly or in pairs, and a field test was carried out at Varna in 1972. Tests on the control of P. saucia were conducted on peppers [Capsicum] grown in a greenhouse at Petrich. From the results of these experiments it is concluded that effective control of A. segetum is given by sprays of endosulfan (Thiodan 35 EC) with methyl-parathion (Fostiol 40 EC) (100 + 150 g/decare), endosulfan with mevinphos (Phosdrin 24 EC) (100 + 150 g/decare), endosulfan with monocrotophos (Nuvacron 60 EC) (150 + 150 g/decare), endosulfan alone (350 g/decare) and chlorpyrifos (Dursban) (120 g/decare). As the effective dose of endosulfan is high and treatment therefore costly, this insecticide should not be used alone unless no alternative is available. Treatment should be applied before the bulk of the larval population has reached the sixth instar and should be followed with a shallow cultivation of the soil. P. saucia can be controlled with a poison bait of 125 g trichlorphon (Diplerex 80), 10 kg wheat bran, 0.5 kg sugar (or 1 kg molasses) and 8-10 litres water applied at 3 kg/decare or with chlorpyrifos (125 g/decare) applied with the irrigation water.

8. Barnes, D. K. A. and P. Convey. 2005. Odyssey of Stow-Away Noctuid Moths to Southern Polar Islands. Antarctic Science 17, no. 3:307-311. Abstract: High southern latitude island environments are unusual in having relatively low or, in some cases, no non-indigenous species (NIS). Here we describe the accidental transport and survivorship of moths (Lepidoptera, Noctuidae) on a research vessel travelling from southern South America (Montevideo, Uruguay) first to the cool temperate Falkland Islands and then onwards to Maritime Antarctic Signy Island (South Orkney Islands). On the vessel's arrival at Stanley, Falkland Islands, from Montevideo we found eight live (and 30 dead) individuals of two species of South American noctuid moth (Pseudaletia adultera Schaus and Peridroma saucia (Hubner)), presumed to have been attracted to the ship's lights while in port. Neither of these is indigenous to the Falkland Islands. Five of the eight living moths (all P. adultera) survived the four days the ship was moored in Stanley and one survived a further four day journey across the Polar Front to Signy Island. Southern oceanic islands are particularly vulnerable to invasion by NIS, with human (shipping) activities being the main route of arrival. With increasing shipping throughout this region some measures have been proposed or adopted to reduce the risk of NIS transfer.

10. Berry, R. E, S. J Yu, and L. C Terriere. 1980. Influence of host plants on insecticide metabolism and management of variegated cutworm. *Journal of Economic Entomology* 73, no. 6: 771-774. Abstract: In laboratory studies in Oregon, the activity of microsomal aldrin epoxidase in the mid-gut of larvae of the peppermint (Mentha piperita) pest Peridroma saucia (Hb.) fed peppermint leaves was up to 9 times as high as that in larvae fed the leaves of other food-plants, such as lucerne, bush snap beans (Phaseolus vulgaris), garden beets and the weed curly dock (Rumex crispus). Epoxidase levels in larvae fed peppermint leaves were about 6 times as high as those in larvae fed a semidefined artificial diet. Enzyme activity was higher in larvae collected from peppermint fields than in laboratory-reared larvae, and was much higher in the fifth and sixth instars than in the fourth. Larvae fed peppermint leaves were more tolerant of acephate, methomyl and malathion than those fed bush snap bean leaves..

11. Bibolini, C. 1970. Biology and damage in the Pisa district of Peridroma saucia Hb. (Lep. Noctuidae) with reference to its geographic distribution, world dietology and relative control measures. *Frustula Entomologica* 10, no. 3: 1-98. Abstract: Following an outbreak of Peridroma saucia Hb. on young lettuce and tomato plants in a greenhouse at Pisa in 1966, a detailed study was made of this Noctuid from observations in the district and from the literature of other countries, especially North America, where infestations have at times been much more severe. Information is given especially on its geographic distribution, food-plants (a list of which is presented), life-history and habits. *P. saucia* attacks a wide variety of wild and cultivated food-plants, including trees, shrubs, ornamentals, fibre crops, cereals and grasses, but it is a pest mainly of garden vegetables. In the Pisa area it has four generations a year, varying in length according to climatic conditions, and the pupae overwinter; adults appear in February-April, June-July, July-August and September-October. Pairing occurs soon after adult emergence and oviposition begins a day later, the females laying 350-1800 eggs each in 3-19 days in large masses on the lower surface of the leaves. The larvae at first are gregarious and visible during the day, but from the fourth larval instar onwards they feed only at night. Pupation takes place in the soil. The egg, larval and pupal stages last 4-32, 23-67 and 13-60 days, respectively. The larvae cut off the leaves of seedlings, permit rotting in plants with a heart such as lettuce, attack the fruits as well as the leaves of tomato and feed on plant stems and even tree bark if leaves are not available. Control can be achieved by bran baits poisoned with a preparation of arsenic such as paris green (which are especially suitable for older larvae and for protecting food crops, seeds and woody plants), sprays of parathion or trichlorphon (against young larvae on forage or flowering plants), deep and thorough soil cultivation (against full-fed larvae and pupae), removal of weeds, rolling of grassland if larval migration is observed, collars of metal or tarred paper placed round the trunk of fruit trees and other woody plants to prevent
larvae climbing them at night to feed, and catching of adults in light-traps..


13. Bourner, T. C. and J. S. Cory. 2004. Host Range of an NPV and a GV Isolated From the Common Cutworm, Agrotis Segetum: Pathogenicity Within the Cutworm Complex. *Biological Control* 31, no. 3:372-379. Abstract: The term cutworm covers a range of species with a similar life history that can be very damaging pests on a wide range of crops. Attacks by cutworms are often made up of more than one species; thus, the most cost effective microbial control agent needs to be pathogenic for multiple species within this complex. In this study we investigate the host range of Agrotis segetum NPV and A. segetum GV for other cutworm species and closely related Noctuinae. Eight species, A. segetum, Agrotis ipsilon, Agrotis exclamationis, Agrotis puta, Noctua comes, Peridroma saucia, Xestia sexstrigata, and Xestia xanthographa, were clearly susceptible to AgseNPV, which was confirmed by DNA analysis. Aglais urticae, Diarsia rubi, Noctua pronuba, and Xestia c-nigrum were not susceptible to AgseNPV at the doses used. Noctua fimbriata, Noctua janthina, and Ochroplura plecta gave ambivalent results: larvae died of NPV infection when they were challenged with AgseNPV, but these individuals only produced weak positives in a squash blot analysis and there was insufficient DNA for confirmation by restriction endonuclease profiling. These ambivalent results could suggest either a weak infection by AgseNPV or partial homology between their own virus and AgseNPV. The untreated control insects of several species died of NPV infection, which indicates that these field-collected insects were probably carrying a vertically transmitted NPV. Fewer species were tested with AgseGV and only N. pronuba and N. comes were susceptible. N. fimbriata and Helicoverpa armigera were not susceptible to AgseGV. Crown Copyright (C) 2004 Published by Elsevier Inc. All rights reserved.

14. Brandenburg, R. L. 1985. The effect of field applications of insecticides for variegated cutworm, Peridroma saucia (Hubner) (Noctuidae: Lepidoptera) control on non-target arthropods in alfalfa. *Journal of the Kansas Entomological Society* 58, no. 3:437-441. Abstract: The non-target impact of 3 insecticides applied for the control of the noctuid Peridroma saucia was evaluated in both short and tall lucerne in Missouri. Chlorpyrifos and methomyl proved more detrimental to beneficial arthropods (including predacious Hemiptera, syrphids, chrysopids, coccinellids and spiders) than did carbaryl, but the first 2 compounds also controlled Acrystosiphon pismum. Carbaryl-treated plots usually had fewer beneficial arthropods 24 h after treatment than did untreated plots; however, no increases in Acrystosiphon populations were observed 7 or 14 days after treatment in successive years on stubble lucerne, although on tall lucerne significantly larger numbers of A. pismum were seen 7 days after treatment with carbaryl than with chlorpyrifos or methomyl.


18. Buntin, G. D., L. P. Pedigo, and W. B. Showers. 1990. Temporal occurrence of the variegated cutworm (Lepidoptera: Noctuidae) adults in Iowa with evidence for migration. *Environmental entomology* 19, no. 3:603-608. Abstract: Adult activity and ovarian dynamics of the variegated cutworm, Peridroma saucia (Hubner), were studied during 3 yr by using blacklight traps. Initial mating in females coincided with ovarian development, with females continuing to mate up to six times during their lives. Adult catches, ovarian dynamics, and degree-day calculations indicated that P. saucia has three generations each year in Iowa. Very few preovipositional females were collected during the spring flight. This observation and the strong association of adult activity during the spring with weather patterns resulting in southerly winds suggested that P. saucia adults migrate into the state each spring when weather conditions are favorable. Flights during June through November contained a large portion of preovipositional females. Degree-day calculations also revealed that adults collected during June and July were the progeny of spring migrants, but temporally distinct influxes of migrants may produce distinct peaks of adult activity during June and July. Degree-day calculations and the collection of a few preovipositional females during the spring suggested that P. saucia may overwinter as pupae, which may produce adults that contribute to the influx of migrants in the spring.

19. Byers, J. R. and D. L. Struble. Monitoring population levels of eight species of noctuids with sex- attractant traps in southern Alberta, 1978-1983: specificity of attractants and effect of target species abundance. *Canadian Entomologist* 119[6], 541-556. 1987. Abstract: The life history and economic status of each species is summarized and the monitoring methodology is described. The attractants for redbacked cutworm Euxoa ochrogaster, darksided cutworm E. messoria, pale western cutworm Agrotis orthogonia, and army cutworm E. auxiliaris were highly specific and >99% of the moths caught were of the target species. Specificity of the attractants for clover cutworm Discestra trifolii and Leucania commoides was also high, averaging 98.3 and 96.6%, respectively. The attractants for variegated cutworm Peridroma saucia and bertha armyworm Mamestra configurata were less specific but the proportion of target species exceeded 80% in those years when either species was relatively abundant. -from Authors
20. Byers, J. R., D. L. Strubbe, and G. B. Schaalje. Monitoring population levels of eight species of noctuids with sex-attractant traps in southern Alberta, 1978-1983: consistency of trap catches and precision of population estimates. Canadian Entomologist 119[6], 557-566. 1987. Abstract: Clover cutworm Dicestra trifolii, variegated cutworm Peridroma saucia, bertha armyworm Mamestra configurata and Leucania commeoides were monitored during spring and early summer, and redbacked cutworm Euxoa ochrogaster, darksided cutworm E. messoria, pale western cutworm Agrotis orthogonia and army cutworm E. auxiliaris during late summer and fall. The ranking of moth catches among locations within years was highly consistent, indicating that the spatial pattern of abundance within the survey area remained stable during each flight period. The corollary is that differences in population levels among locations were being consistently detected. -from Authors


22. Champagne, D. E, M. B Isman, K. R Downum, and G. H N Towers. 1993. Insecticidal and growth-reducing activity of foliar extracts from Meliaceae. Chemoecology 4, no. 3/4:165-173. Abstract: Thirty-one species in 20 genera of the plant family Meliaceae were assayed for the production of growth-inhibiting phytochemicals using the generalist herbivore Peridroma saucia. Most plant species were inhibitory when methanolic extracts were incorporated into artificial diets at concn at or below those occurring naturally. In general, members of the subfamily Melioideae were more inhibitory than members of the Swietenioideae. Extracts of deciduous species with short leaf lifetimes were significantly more inhibitory than those of evergreen species with longer leaf lifetimes. In a smaller sample of species, evergreen species showed a trend towards having tougher leaves than deciduous species. These results supported the resource availability hypothesis and suggested that life history attributes may be of some value in selecting plants for phytochemical prospecting..


24. Ciampolini, M. and S. Zangheri. 1975-1976. Sesamia nonagrioides (Lef.) and Peridroma saucia Hb. (Lep. Noctuidae) injurious to flower crops. Bollettino di Zoologia Agraria e di Bachicoltura 13:37-47. Abstract: As a result of observations in Italy in 1972-74, information is given on the life-history, habits and control of Sesamia nonagrioides (Lef.), which caused 30-90% loss of gladiolus flowers in the south of the Province of Latium (being most injurious to the summer and autumn crops), and of Peridroma saucia Hb., which caused up to 60% loss of carnations in the Ligurian Riviera in late summer and autumn; the seasonal presence of the second species is discussed in relation to current knowledge of
its migration, and data on both species are compared with those from the literature of Italy and other countries. Among the chemical compounds tested for control, acephate appeared to be the most effective; it was applied at the rate of 0.5 kg toxicant/ha every 10 days beginning when the gladiolus plants were 10-15 cm high against S. nonagrioides, and at a concentration of 75 g toxicant/hl every 10-12 days during the adult flight period against P. saucia.


26. Dillon, R. J. and V. M. Dillon. 2004. The Gut Bacteria of Insects: Nonpathogenic Interactions. *Annual Review of Entomology* 49:71-92. Abstract: The diversity of the Insecta is reflected in the large and varied microbial communities inhabiting the gut. Studies, particularly with termites and cockroaches, have focused on the nutritional contributions of gut bacteria in insects living on suboptimal diets. The indigenous gut bacteria, however, also play a role in withstanding the colonization of the gut by non-indigenous species including pathogens. Gut bacterial consortia adapt by the transfer of plasmids and transconjugation between bacterial strains, and some insect species provide ideal conditions for bacterial conjugation, which suggests that the gut is a "hot spot" for gene transfer. Genomic analysis provides new avenues for the study of the gut microbial community and will reveal the molecular foundations of the relationships between the insect and its microbiome. In this review the intestinal bacteria is discussed in the context of developing our understanding of symbiotic relationships, of multitrophic interactions between insects and plant or animal host, and in developing new strategies for controlling insect pests.

27. El-Aswad, A. F., S. A. M. Abdelgaleil, and M. Nakatani. 2004. Feeding Deterrent and Growth Inhibitory Properties of Limonoids From Khaya Senegalensis Against the Cotton Leafworm, Spodoptera littoralis. *Pest Management Science* 60, no. 2:199-203. Abstract: Three rearranged phragmalin-type limonoids, khayanolide A, khayanolide B and 1-O-acetylkhayanolide B, and a mexicanolide-type limonoid, khayalactol, have been isolated from the stem bark of Khaya senegalensis (Desr) A Juss (Meliaceae). The antifeedant and growth-inhibitory activities of the isolated compounds were evaluated on Spodoptera littoralis (Boisduval). When added to an artificial diet, khayanolide A, khayanolide B and 1-O-acetylkhayanolide B showed antifeedant activity in a concentration-dependent manner. Khayalactol exhibited strong antifeedant activity without significant differences at an of the tested concentrations (7.5-100 mg kg(-1)). Khayanolide B was the most potent antifeedant with an EC50 of 2.19 mg kg(-1). The results also revealed that the isolated compounds caused marked larval growth inhibition on S. littoralis after 7 days of feeding on treated diet; this effect was concentration-dependent. Khayanolide B was the most active growth inhibitor among the isolated compounds, with an EC50 of 6.96 mg kg(-1). (C) 2003 Society of Chemical Industry.
28. Estela, B. 2005. Ichneumonoids (Hymenoptera) Parasitoids of Cutworms Group in Alfalfa Pastures (Medicago Sativa L.) In Central Argentina. *Neotropical Entomology* 34, no. 3:407-414. Abstract: The knowledge about the role of natural enemies is crucial for integrated pest management systems. Parasitoids are considered most important for biological control, although the quantitative dimension of their effect on hosts is not always known. The objective of the present study was to survey the parasitoids of cutworms in the northeastern area of La Pampa Province, Argentina. The field work was conducted during four years (1999 to 2002). Larvae of Agrotis gypaetina Guenee, A. malefida (Guenee) and Peridroma saucia (Hubner) (Lepidoptera: Noctuidae) were collected in a fortnightly interval in alfalfa pastures, in order to establish the incidence of hymenopterous parasitoids in three areas of the eastern physiographic area of La Pampa, Argentina. These larvae were kept in breeding laboratory and fed with artificial diet until emergence of the parasitoids. The larvae were then identified and quantified. Parasitoid species of four genera of Ichneumonidae were found: Alophophion sp. Cushman (Ophioninae), Campoletis sp. Forster (Campopleginae), Thymebatis spp. Brethes (two species) and Eutanyacra sp. Cameron (Ichneumoninae); and one species of Braconidae: Glyptapanteles bourquini (Blanchard) (Microgastrinae). New host species for Alophophion, Thymebatis and Eutanyacra were recorded. Alophophion was responsible for 80 % of the parasitoidism, was present in all the regions studied and parasitized all the species of cutworm found.

29. Fuchs, T. W, J. A Harding, and T. Dupnik. 1972. Insecticidal control of the variegated cutworm on cantaloupes. *Progress Report, Texas Agricultural Experiment Station* 3135:1-4. Abstract: Thirty chemicals were evaluated for controlling Peridroma saucia on cantaloup melons. The percentage of damaged fruit varied widely between replicates, but numerically the most effective treatments were Orthene (O,S-dimethyl N-acetyl phosphoramidothioate) diazinon, Thuricide, Leptophos (O-(4-bromo-2,5-dichlorophenyl) O-methyl phenylphosphonothioate) and methomyl. No phytotoxicity was observed from any treatment 2 days after application..


31. Gaylor, M. J., S. J. Fleischer, D. P. Muehleisen, and J. V. Edelson. Insect populations in cotton produced under conservation tillage. *Journal of Soil & Water Conservation* 39[1], 61-64. 1984. Abstract: A damaging population of variegated cutworm Peridroma saucia developed in one cotton Gossypium hirsutum crop in conservation tillage with crimson clover Trifolium incarnatum used as a cover crop. Tarnished plant bug Lygus lineoloris and bollworm-budworm Heliothis spp. populations found in cotton grown under conservation tillage with legume cover crops were related to the stressed condition of cotton. Yields were reduced by the clover cover crop; yields were not reduced by conservation tillage using no winter cover or rye Secale cereale as a cover.-from Authors

33. Harris, C. R and G. B Kinoshita. 1977. Influence of posttreatment temperature on the toxicity of pyrethroid insecticides. Journal of Economic Entomology 70, no. 2:215-218. Abstract: The effects of different post-treatment temperatures on the toxicity of direct sprays (in a Potter spray tower) and soil applications of pyrethroid insecticides to various insects were evaluated in laboratory studies in Canada. Direct sprays of pyrethrins, resmethrin, permethrin (FMC 33297), Shell WL-41706 [cyano(3-phenoxyphenyl)methyl 2,2,3,3-tetramethylcyclopropanecarboxylate] and Shell WL-43775 [cyano(3-phenoxyphenyl)methyl 4-chloro- alpha -(1-methylethyl)benzeneacetcate] were from 2.7 to 3.6 times as toxic to first-instar nymphs of Gryllus pennsylvanicus Burm. at 15 deg C as they were at 32 deg C. Pemthrin was 2.6, 3.6 and 7.4 times as toxic to adults of Phyllotreta cruciferae (Goeze) and of Delia antiqua (Mg.) (Hylemya antiqua). and third-instar larvae of Peridroma saucia Hb., respectively, at 15 deg C as at 32 deg C. Endosulfan showed a positive, carbaryl a bimodal, and permethrin and DDT a negative temperature coefficient of toxicity at 15, 22, 27 and 32 deg C. When incorporated into mineral and organic soil, permethrin was slightly more toxic to G. pennsylvanicus at 15 deg C than at 32 deg C.

34. Harris, C. R, H. J Svec, and R. A Chapman. 1978. The effectiveness and persistence of some insecticides used for control of the variegated cutworm attacking tomatoes in southwestern Ontario. Proceedings of the Entomological Society of Ontario. 1977 108:63-68. Abstract: In tests in the laboratory in Ontario, the pyrethroids permethrin, WL-41706 (cyano(3-phenoxyphenyl)methyl 2,2,3,3-tetramethylcyclopropanecarboxylate) and WL-33775 (cyano(3-phenoxyphenyl)methyl 4-chloro- alpha -(1-methylethyl)benzeneacetate) were more toxic by direct contact with third-instar larvae of Peridroma saucia Hb. than methomyl or chlorpyrifos. Carbofuran, endosulfan, carbaryl and azinphos-methyl were about one-tenth as toxic. Third-instar larvae were about 2.9 and fifth-instar larvae 3.7 times as tolerant of permethrin as first-instar larvae. The 3 pyrethroids were effective against third- and fourth-instar larvae at rates as low as 62.5 g/ha when applied to the surface of moist sand. Methomyl, chlorpyrifos and carbaryl were less effective. All soil treatments were less effective against sixth- and seventh-instar larvae. In microplot field tests, permethrin, WL-41706 or WL-43775 applied at 140 g/ha caused 98, 73 and 63% mortality, respectively, to third- to fourth-instar larvae infesting tomato. Chlorpyrifos, carbaryl, methomyl and carbofuran were not effective, even though applied at higher rates. Thirty days after treatment with 140 g/ha permethrin, WL-41706 or WL-43775, residues detected on tomatoes were 0.12, 0.03 and <0.01 p.p.m., respectively.

to Peridroma saucia was evaluated. Menthol completely inhibited pupation at doses approximately those in peppermint (0.05-0.2% wet wt). Limonene (0.2%), menthone (0.1%, 0.2%), and pulegone (0.1%) also inhibited pupation. Growth, feeding, and pupation were not affected when larvae ingested limonene (0.05% or 0.1%) or ?-pinene (0.05-0.2%). The median lethal dose for pulegone applied topically to sixth instars was 1007 ?g/g; for menthone, 2478 ?g/g; and for ?-pinene, 7925 ?g/g. -from Authors

36. Inomata, S.I., S. Tsuchiya, K. Ikeda, O. Saito, and T. Ando. Identification of the Sex Pheromone Components Secreted by Female Moths of Peridroma Saucia (Noctuidae : Noctuinae). Bioscience, Biotechnology and Biochemistry 66[11], 2461-2464. 2002. Abstract: The variegated cutworm, Peridroma saucia Hubner, is a lepidopteran pest to a large number of crops in Canada, the United States, and Europe. It was probably naturalized in Japan in the 1970s. The pheromone glands of the female moth include two components with electroantennographic activity in a ratio of 3:1. GC-MS analyses of pheromone extracts untreated and treated with dimethyl disulfide revealed the major component to be (Z)-11-hexadecenyl acetate and the minor component to be (Z)-9-tetradecenyl acetate. The synthetic pheromone was used to attract a large number of males in a vegetable field in Tokyo, which suggests that this species has already become a harmful pest in Japan.

37. Isman, M. B. Growth inhibitory and antifeedant effects of azadirachtin on six noctuids of regional economic importance. Pesticide Science 38[1], 57-63. 1993. Abstract: Examined black army cutworm Actebia fennica, bertha armyworm Mamestra configurata, variegated cutworm Peridroma saucia, zebra caterpillar Melanchra picta, Asian armyworm Spodoptera litura and cabbage looper Trichoplusia ni. When added to an artificial diet, azadirachtin inhibited neonate larval growth of all species in a dose-dependent fashion. EC50 values (dietary concentration reducing larval growth by 50% relative to controls) following ten days of feeding ranged from 0.12-0.24 mg kg-1 but without significant differences between species. However, when second-instar larvae were offered a choice, only larvae of P. saucia and S. litura discriminated between a control diet and diet containing azadirachtin at concentrations up to 0.4 mg kg-1. A more sensitive behavioural bioassay using fourth-instar larvae indicated that S. litura was the most sensitive to the antifeedant effects of azadirachtin (EC50 = 1.25 ng cm-2), whereas A. fennica was the least (EC50 = 40.7 ng cm-2). Topical treatment of fourth-instar larvae with 50 or 100 ng of azadirachtin resulted in significant inhibition of subsequent growth, diet consumption, and dietary utilization. -from Author

38. Isman, M. B., P. J. Gunning, and K. M. Spollen. Tropical Timber Species as Sources of Botanical Insecticides. ACS Symposium Series 658, 27-37. 1997. Abstract: Screening of wood extractives from tropical timber species and other trees against pestiferous lepidopterans such as the tobacco cutworm, Spodoptera litura and the variegated cutworm, Peridroma saucia, indicates the presence of insecticidal and growth inhibitory factors in certain genera. The mahogany family (Meliaceae) includes several important timber species in the genera
Swietenia, Khaya, Cedrela and Entandrophragma, but also includes the Indian neem tree, Azadirachta indica, already well-known as a source of potent botanical insecticides. Strong bioactivity against insects has been observed in extracts from species of Aglaia, Trichilia and Chisocheton. In most cases, limonoid triterpenes, characteristic secondary metabolites of the Meliaceae, are responsible for bioactivity, but in the case of Aglaia, the insecticidal principles are modified benzofurans. Extractives from several genera of the African walnut family (Olacaceae) have potent bioactivity as larval growth inhibitors, but this family has had sparse chemical characterization to date. Extractives from the Dipterocarpaceae, the most important family of timber species in tropical Asia, were essentially inactive in our screening program. However, bark, woodwaste and sawdust from certain commercially harvested timber species could be exploited for their biologically-active constituents.

39. Isman, M. B., O. Koul, J. T. Arnason, J. Stewart, and G. S. Salloum. Developing a neem-based insecticide for Canada. Memoirs - Entomological Society of Canada 159, 39-47. 1991. Abstract: Leaves of Azadirachta indica (Meliaceae) have been used for centuries in India to protect stored grain from insect attack. The author document the potent antifeedant action of azadirachtin in laboratory bioassays against European corn borer Ostrinia nubilalis and variegated cutworm Peridroma saucia and the molt-disrupting action of the compound in the migratory grasshopper Melanoplus sanguinipes and the large milkweed bug Oncopeltus fasciatus. Both antifeedant and insect growth regulatory activities of various samples of neem seed oil are correlated to azadirachtin concentrations in the oils. Field trials of an experimental neem insecticide conducted against pests of crucifers, corn, and potato in British Columbia, Ontario, and Prince Edward Island, respectively, indicate that the neem insecticide provides pest control as effective as or better than pyrethrum, the current botanical insecticide of choice for organic growers. -from Authors


41. Koul, O. 1999. Insect Growth Regulating and Antifeedent Effects of Neem Extracts and Azadirachtin on Two Aphid Species of Ornamental Plants. Journal of Biosciences 24, no. 1:85-90. Abstract: Leaf disc choice test bioassay demonstrated that formulated neem seed extracts were highly deterrent and growth regulatory to rose aphid, Microsiphum rosae (L.) and Chrysanthemum aphid, Macrosiphoniella sanbornii (Gillete). Effective concentrations to produce 50% feeding deterrence was 0.80 and 0.84% respectively for 2nd instar nymphs irrespective of bioassay duration. The disruption of aphid feeding was related to the presence of azadirachtin concentration in the extract. The toxicity on contact from the leaf surface or via topical application due to azadirachtin was significantly different and topical treatment was at least 7 times more effective for both species. Thus growth regulatory effects of azadirachtin were influenced by the host plant and the stage of treatment. Field evaluation with formulated neem extracts revealed the effect to be more of growth regulatory nature thereby
showing that azadirachtin is a physiological toxin for aphid species. Neem seed extracts reduced the population of aphid on respective host plants significantly, EC50 values being 0.88 and 0.96% for M. rosae and M. sanbornii respectively.

42. Koul, O., W. M. Daniewski, J. S. Multani, M. Gumulka, and G. Singh. 2003. Antifeedant Effects of the Limonoids From Entandrophragma Candolei (Meliaceae) on the Gram Pod Borer, Helicoverpa Armiger (Lepidoptera : Noctuidae). Journal of Agricultural and Food Chemistry 51, no. 25:7271-7275. Abstract: The biological activity of the limonoids prieurianin and epoxyprieurianin isolated from Entandrophragma candolei (Harms) (Meliaceae) and their respective acetates was assessed using the gram pod borer, Helicoverpa armiger (Hubner) (Lepidoptera: Noctuidae). The compounds exhibited strong antifeedant activity in a diet choice bioassay with epoxyprieurianin acetate being most effective with 48.3 ppm deterring feeding by 50% (DI50) and prieurianin the least effective (DI50 = 91.4 ppm). The effect on growth of larvae was concomitant with the reduced feeding by neonate and third instar larvae. In nutritional assays, all the compounds reduced growth and consumption when fed to larvae without any effect on efficiency of conversion of ingested food (ECI), suggesting antifeedant activity alone. No toxicity was observed nor was there any significant affect on nutritional indices following topical application, further suggesting that prieurianin-type limonoids act specifically as feeding deterrents.

43. Koul, O., M. B. Isman, and J. T. Arnason. 1994. Toxicokinetics of [3H]-dihydroazadirachtin in the variegated cutworm Peridroma saucia. Archives of insect biochemistry and physiology 25, no. 2:95-106. Abstract: The excretion, retention, and tissue distribution of [3H]-dihydroazadirachtin was investigated in the variegated cutworm, Peridroma saucia (Noctuidae). The candidate compound was rapidly cleared from the hemolymph following either oral exposure or topical administration, with maximum concentrations at 6 h post-treatment and peak appearance of label in the frass at 12 h. However, approximately 45 and 55% of the labelled material was retained in the body at 72 h in respective treatments. Major depots for retained radioactivity were the gut (24% of the administered oral dose, 18.8% of the administered topical dose) and integument (12.2% of the oral dose and 30.7% of the topical dose). The variation in tissue distribution of dihydroazadirachtin with respect to the mode of application is discussed. A single polar metabolite fraction was obtained from the frass of dihydroazadirachtin-fed larvae. The physiological and behavioral effects of 22,23-dihydroazadirachtin and azadirachtin are quantitatively similar.

44. Koul, O., H. Kaur, S. Goomber, and S. Wahab. 2004. Bioefficacy and Mode of Action of Rocaglamide From Aglaia Elaeagnoidea (Syn. A-Roxburghiana) Against Gram Pod Borer, Helicoverpa Armiger (Hubner). Journal of Applied Entomology 128, no. 3:177-181. Abstract: Rocaglamide, a highly substituted benzofuran, was isolated and identified as the main biologically active component in Aglaia elaeagnoidea (syn. A. roxburghiana) for gram pod borer Helicoverpa armiger (Hubner). Addition of rocaglamide to an artificial diet retarded the growth of neonate larvae in a dose-dependent manner with EC50
values of 0.76 p.p.m. These values compared favourably with azadirachtin (EC50 = 0.23 p.p.m.). However, azadirachtin was apparently more potent than rocaglamide in inducing growth inhibition via oral administration to these first stadium larvae. The candidate compound was found to have LD50 and LD95 values of 0.40 and 1.02 mug per larva, respectively, in topical application against third instar larvae 96 h post-treatment. However, these values for azadirachtin were 8.16 and 25.8 mug per larva for the same period. This shows that azadirachtin was less effective against third instar H. armigera larvae in inducing acute toxicity via topical treatment in comparison with rocaglamide. However, severe morphological larval deformities were observed in such azadirachtin-treated larvae during the process of ecdysis. The cytotoxic nature of rocaglamide was established by evaluating dietary utilization and the results did not implicate any antifeedant effect but the toxicity-mediated effect due to reduced efficiency of conversion of ingested food. It was obvious that feeding deterrence is not the primary mode of action but a centrally mediated effect, which could be due to the induced cytotoxicity at non-specific cellular levels.

45. Koul, O., J. S. Multani, S. Goomber, W. M. Daniewski, and S. Berlozecki. 2004. Activity of Some Nonazadirachtin Limonoids From Azadirachta Indica Against Lepidopteran Larvae. *Australian Journal of Entomology* 43:189-195. Abstract: The biological activity of azadirachtin, nimbocinol, azadiradione and salannin isolated from Azadirachta indica A. Juss. (neem) was assessed alone and in combination against the cotton bollworm, Helicoverpa armigera (Hubner) and cluster caterpillar, Spodoptera litura (F) (Lepidoptera: Noctuidae). Nimbocinol exhibited growth inhibitory activity in artificial diet bioassays with 82.4 and 92.2 mg kg(-1) concentrations inhibiting growth by 50%, respectively, in the two species. This efficacy was almost comparative to azadiradione (EC50 = 109.6 and 102.1 mg kg(-1)) and salannin (EC50 = 72.2 and 70.2 mg kg(-1)). Azadirachtin was the most active neem allelochemical against both insect species. In nutritional analysis, only nimbocinol and azadiradione reduced the efficiency of conversion of ingested food (ECI) in feeding experiments, indicating toxic rather than antifeedant effects. In a combination, when azadirachtin was present in a mixture, it always dominated in its efficacy and EC50 values did not deviate much from the individual efficacy of azadirachtin (0.23 and 0.21 mg kg(-1), against H. armigera and S. litura larvae, respectively). However, enhanced activity among structurally variable molecules was observed, i.e., when salannin combines with nimbocinol or azadiradione, rather than structurally similar molecules like nimbocinol with azadiradione. The activity among nonazadirachtin limonoids in specific combination as opposed to the structural chemistry having explicitly two different modes of action, like feeding deterrence and chronic toxicity, may be playing a significant role in the multicomponent system.

Juss. was assessed using the gram pod borer, Helicoverpa armigera (Hubner), and Asian armyworm, Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae), alone and in combination with other limonoids, gedunin, salannin, nimbinene, and azadirachtin. The compound exhibited growth inhibitory activity in artificial diet bioassays, with 24.2 and 21.5 ppm, respectively, inhibiting growth by 50%. This efficacy was higher in comparison to gedunin (EC50 = 50.8 and 40.4 ppm), salannin (EC50 = 74.5 and 72.0 ppm), and nimbinene (EC50 = 391.4 and 404.5 ppm). Azadirachtin, however, remained the most active neem allelochemical against both insect species. Nutritional assays clearly demonstrated that, though relative consumption and growth rates of fourth instar larvae were reduced, gedunin-type compounds induced physiological toxicity, evident by reduced efficiency of conversion of ingested food (ECI) in feeding experiments. Salannin and nimbinene, on the contrary, induced concentration-dependent feeding deterrence only. In feeding experiments, combinations of the compounds revealed that when azadirachtin was present in a mixture, EC50 values did not deviate from the individual efficacy of azadirachtin (0.26 and 0.21 ppm, respectively) against H. armigera and S. litura larvae. However, a combination without azadirachtin did show a potentiation effect with potent EC50 values among structurally different molecules, i.e., when salannin or nimbinene was combined with 6beta-hydroxygedunin gedunin rather than structurally similar salannin + nimbinene or 6beta-hydroxygedunin + gedunin. Obviously, azadirachtin being the most active compound in neem is not synergized or influenced by any other limonoid, but other non-azadirachtin limonoids were more potent in specific combinations vis-a-vis the structural chemistry of the compound. It is obvious from the present study that potentiation among non-azadirachtin limonoids having explicitly two different modes of action, such as feeding deterrence and physiological toxicity, may be playing a significant role in the potentiation effect.

47. Koul, O., J. S. Multani, G. Singh, and S. Wahab. 2002. Bioefficacy of Toosendanin From Melia Dubia (Syn. M-Azedarach) Against Gram. Pod-Borer, Helicoverpa Armigera (Hubner). Current Science 83, no. 11:1387-1391. Abstract: The antifeedant and growth-inhibitory activities of Melia dubia (syn. M. azedarach) methanol extract and the allelochemical toosendanin isolated from this fraction to Helicoverpa armigera were investigated. Artificial diet bioassay using neonate larvae showed the effect on growth in a dose-dependent manner. After seven days of feeding, EC50 value (concentration inhibiting larval growth by 50%. relative to controls) for toosendanin (98% purity) was 26.8 ppm, and dose-response relationship was highly significant in linear regression analysis (P < 0.05). FI50 value (dietary concentration showing 50% feeding inhibition) for toosendanin in third-instar larvae was 56.6 ppm. The results from dietary utilization experiments on fourth-instar larvae revealed reduction in relative growth and consumption rates after oral administration of toosendanin, with a concomitant reduction in efficiency of conversion of ingested food (ECI) at higher concentration only. However, there was significant decrease in efficiency of conversion of digested food (ECD). following topical treatment, there was significant decrease in relative growth rate and relative consumption rate, although in this case ECI, ECD and approximate digestibility were not
significantly reduced. In view of the present findings, toosendanin seems to-specifically induce feeding deterrence in H. armigera larvae and apparently stimulates deterrent receptor cells. What is obvious from our nutritional studies is that food intake in most of the larvae of H. armigera is suppressed due to toosendanin, which apparently reduces neural-input from taste cells specialized to detect feeding stimulants. Particularly in topically-treated insects, no toxicity-mediated inhibition was recorded, and still the growth was inhibited in relation to reduced feeding. However, feeding inhibition in a much more intricate manner, which is subsequently responsible for the growth inhibition of insects.

48. Koul, O., G. Singh, R. Singh, and J. S. Multani. 2005. Bioefficacy and Mode-of-Action of Aglaroxin A From Aglaia Elaeagnoidea (Syn. A-Roxburghiana) Against Helicoverpa Armigera and Spodoptera Litura. *Entomologia Experimentalis Et Applicata* 114, no. 3:197-204. Abstract: The bioefficacy of aglaroxin A from Aglaia elaeagnoidea (syn. A. roxburghiana) was assessed using the gram pod borer, Helicoverpa armigera (Hubner), and Asian armyworm, Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae). The compound exhibited strong growth inhibition in a diet bioassay, with 0.67 p.p.m: and 0.78 p.p.m. of the compound reducing growth by 50% in H. armigera and S. litura neonate larvae, respectively, whereas a growth inhibition of 95% was achieved at 2.36 p.p.m: and 2.41 p.p.m., respectively; this was comparable to azadirachtin treatments used as a control. Aglaroxin A was toxic to various stadia. Nutritional analysis revealed the antifeedant properties of the compound; however, nutritional indices indicated that the reduction in growth of the larvae was not entirely due to starvation, but partly due to the toxic effects of the ingested compound. This was further confirmed in topical treatments. When relative growth rate was plotted against relative consumption rate, the growth efficiency of larvae fed on a diet containing aglaroxin A was significantly less than that of control larvae. These results further indicate that aglaroxin A acts as both antifeedant and chronic toxin. Morphologically deformed or partially pupated insects were obtained after 5th instar larvae were treated with aglaroxin A. Such developmental inhibition during ecysis was not due to depletion of the moulting hormone, as treated larvae, when provided with exogenous 20-hydroxyecdysone, did not show any recovery from the effect. However, it is obvious from the present findings that aglaroxin A activity does not absolutely follow the pattern of azadirachtin or the more related compound roca glamide known in lepidopterans.

49. Koul, O., G. Singh, R. Singh, J. Singh, W. M. Daniewski, and S. Berlozecki. 2004. Bioefficacy and Mode-of-Action of Some Limonoids of Salannin Group From Azadirachta Indica A. Juss and Their Role in a Multicomponent System Against Lepidopteran Larvae. *Journal of Biosciences* 29, no. 4:409-416. Abstract: Biological activities of the salannin type of limonoids isolated from Azadirachta indica A. Juss were assessed using the gram pod borer Helicoverpa armigera (Hubner) and the tobacco armyworm Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae). Inhibition of larval growth was concomitant with reduced feeding by neonate and third instar larvae. All three compounds
exhibited strong antifeedant activity in a choice leaf disc bioassay with 2.0, 2.3 and 2.8 µg/cm² of 3-O-acetyl salannol, salannol and salannin, respectively deterring feeding by 50% in S. litura larvae. In nutritional assays, all three compounds reduced growth and consumption when fed to larvae without any effect on efficiency of conversion of ingested food (ECI), suggesting antifeedant activity alone. No toxicity was observed nor was there any significant affect on nutritional indices following topical application, further suggesting specific action as feeding deterrents. When relative growth rates were plotted against relative consumption rates, growth efficiency of the H. armigera fed diet containing 3-O-acetyl salannol, salannol or salannin did not differ from that of starved control larvae (used as calibration curve), further confirming the specific antifeedant action of salannin type of limonoids. Where the three compounds were co-administered, no enhancement in activity was observed. Non-azadirachtin limonoids having structural similarities and explicitly similar modes of action, like feeding deterrence in the present case, have no potentiating effect in any combination.

50. Landolt, P. J., C. Smithhisler, T. Adams, and R. S. Zack. 2003. An Improved Multi-Component Sex Attractant for Trapping Male Western Yellowstriped Armyworm, Spodoptera Praefica (Grote) (Lepidoptera : Noctuidae). *Agricultural and Forest Entomology* 5, no. 4:333-339. Abstract: 1 Chemical analyses of solvent extracts of pheromone glands of female western yellowstriped armyworm moths Spodoptera praefica (Grote) indicated the presence of (Z)-7-dodecenol (Z)-7-dodecenyl acetate (Z)-9-dodecenyl acetate (Z)-9-tetradecenyl acetate and (Z)-11-hexadecenyl acetate. 2 In field tests of combinations of these chemicals, small numbers of male S. praefica were captured in traps baited with (Z)-7-dodecenyl acetate. Numbers of males captured in traps were greatly increased in response to blends that included both (Z)-7-dodecenyl acetate with either (Z)-9-tetradecenyl acetate (Z)-9-dodecenyl acetate. The combination of (Z)-7-dodecenyl acetate and (Z)-9-tetradecenyl acetate provided the strongest sex attractant for use in trapping male S. praefica. 3 Males of the cabbage looper Trichoplusia ni (Hubner) were captured in traps baited with blends possessing (Z)-7-dodecenyl acetate, and were greatly reduced in traps baited with blends that included (Z)-7-dodecenol. 4 Multi-component blends that included (Z)-7-dodecenol attracted males of the alfalfa looper Autographa california (Speyer). 5 Males of Peridroma saucia (Hubner) and Mamestra configurata Walker were captured in traps that included (Z)-9-tetradecenyl acetate with (Z)-11-hexadecenyl acetate. 6 These responses by other species of moths to S. praefica pheromone components and blends may still complicate the use of any lure for S. praefica.


52. Lighthart, B. 1988. Some changes in gut bacterial flora of field-grown Peridroma saucia (Lepidoptera: Noctuidae) when brought into the laboratory. *Applied and
environmental microbiology 54, no. 7:1896-1898. Abstract: Removal of Peridroma saucia from the field to the laboratory caused little change in the quantity of facultative and aerobic bacteria in the gut but produced significant qualitative and quantitative changes in distinguishable groups of the family Enterobacteriaceae in the gut.

53. Lindquist, R. K. 1977. Cutworm control trials on greenhouse crops in 1976. Ohio Florists’ Association Bulletin 568:8-9. Abstract: Control of the variegated cutworm (Peridroma saucia) was evaluated in tomatoes and chrysanthemums using sprays of resmethrin, Sumithion [fenitrothion], UC 51762, Vydate [oxamyl], Orthene [acephate], PP-557 [permethrin] and Lannate [methomyl] and baits of Dipel [Bacillus thuringiensis] + various carriers, Mesurol [methiocarb], Dylox [trichlorphon] or Sevin [carbaryl]. Resmethrin gave control equal to or better than that for all other materials. Vydate, Sumithion, Lannate and UC 51762 gave fair to good control in one or more trials..

54. Machuca, J. R, J. E Araya, P. V Arretz, and P. I Larrain. 1990. Evaluation of chemical and cultural control for noctuid larvae in Chilean artichokes produced for foreign markets. Crop Protection 9, no. 2:115-118. Abstract: The presence of noctuid larvae on artichoke heads, particularly Copitarsia consueta but also Syngrapha gammoides, Agrotis bilitura [Pseudoleucania bilitura], Peridroma saucia and P. chilenaria, has caused the rejection of Chilean artichokes prior to shipping to foreign markets. This study compares the proportions of damage caused by noctuid larvae throughout the harvest period of fresh artichokes produced for markets in the northern hemisphere. A field trial was conducted in the central valley of Chile, comparing several practices consisting of combinations of traditional or intensive weed control and insecticide use. The damage levels were measured on 6 harvest dates during the 1986 season. The more intense weed control treatment significantly reduced damage by noctuid larvae. Methomyl sprays prior to the first three harvests further reduced damage levels. A combination of methomyl sprays and intensive weed control was the most efficacious treatment. It is estimated that intensive weed control combined with insecticide sprays similar in action to methomyl may help to decrease the number of insecticide applications required to reduce noctuid species populations occurring on artichoke crops under the traditional management of only 2 hoe-weeding controls..

55. Miller, J. C. Temperature-dependent development of Meteorus communis (Hymenoptera: Braconidae), a parasitoid of the variegated cutworm (Lepidoptera: Noctuidae). Journal of Economic Entomology 89[4], 877-880. 1996. Abstract: Development of a parasitoid, Meteorus communis (Cresson), was compared at 8 constant temperatures, while reared on a noctuid host, the variegated cutworm, Peridroma saucia (Hubner), fed a standard artificial diet. Development from oviposition to adult emergence ranged from 15.7 d at 28_C to 61.8 d at 14_C. The temperature requirement for development from egg to exit of the parasitoid larva (3rd instar) from the host was 143 _ 9.9 DD above a developmental threshold of 10.3 _ 0.6_C. Development from the 3rd instar to adult emergence required 132 _ 5.4 DD above a developmental threshold of 8.3
Overall, development from egg deposition to adult emergence required 274 ± 14.5 DD above a developmental threshold of 9.5 ± 0.5°C. The development of M. communis was compared with 3 populations of P. saucia for 3 temperatures.


58. Morris, O. N. and V. Converse. Effectiveness of steinernematid and heterorhabditid nematodes against noctuid, pyralid, and geometrid species in soil. *Canadian Entomologist* 123[1], 55-61. 1991. Abstract: The most parasitic nematodes were Steinernema bibionis for wax moth Galleria mellonella and bertha armyworm Mamestra configurata, Heterorhabditis heliothidis for cereal armyworm Pseudaletia unipuncta, S. feltiae for variegated cutworm Peridroma saucia and S. feltiae for red-backed cutworm Euxoa ochrogaster and spring cankerworm Paleacrita vernata. The most promising nematode for soil applications was S. feltiae against bertha armyworm. -from Authors

59. Nawrot, J., O. Koul, M. B. Isman, and J. Harmatha. 1991. Naturally occurring antifeedants: effects on two polyphagous lepidopterans. *Journal of applied entomology* 112, no. 2:194-201. Abstract: Fourteen plant allelochemicals, all of which are strong antifeedants to stored product coleopterans, were evaluated as antifeedants and larval growth inhibitors against the variegated cutworm, Peridroma saucia, and the bertha armyworm, Mamestra configurata (Lep., Noctuidae). Bisabolangelone, a sesquiterpene, podophyllotoxin, a lignan, and aginosid, a saponin, are strongly deterrent to P. saucia larvae in a feeding choice test. When added to artificial diets, the sesquiterpene lactone bakkenolide A was the most inhibitory to larval growth of neonate cutworms, whereas bisabolangelone was the most inhibitory to neonate armyworms. Toxicity of bakkenolide A, xanthotoxin (a furanocoumarin), and podophyllotoxin to insects is discussed.

Abstract: Interactions between weeds and arthropods occur frequently. This review covers the topic of weed/arthropod interactions, and provides the reader with access to literature in the subject area that is scattered in weed science, entomological, crop production, and ecological journals. We first analyze the current status of weed and arthropod management in the context of multidisciplinary integrated pest management (IPM). The remainder of the review is organized according to the mechanisms driving interactions. The first section deals with interactions driven by trophic relationships, and is subdivided into direct and indirect trophic interactions. Direct trophic interactions occur when pest or beneficial arthropods feed directly on weeds. Indirect trophic interactions occur when arthropod feeding damage to crops impacts weeds through alteration of ecosystem resource availability, or through weeds serving as hosts for alternate prey for beneficial arthropods, or via tritrophic interactions. The second mechanism driving interactions is considered in relation to alteration of the physical habitat by the presence of weeds, such as alteration of temperature within the plant canopy. The third major mechanism driving interactions is based on control tactics for the two types of pests. These are considered from the aspect of direct physical effects, such as tillage, and from the aspect of interactions resulting from the use of pesticides. The latter is divided into direct effects of herbicides and insecticides on non-target pests and beneficials, and on interactions that result from alteration of host plant physiology by pesticides. A conclusion section attempts to place the impact of interactions into an IPM framework, and to indicate where multidisciplinary research involving weed and arthropod management should be focused in the future.

61. Ring, M., T. A. Pfeifer, and T. A. Grigliatti. Identification of a 5' truncated non-LTR-retrotransposon, YAKPs1, from the variegated cutworm, Peridroma saucia, using PCR. Insect Biochemistry and Molecular Biology 26[5], 511-518. 1996. Abstract: Retrotransposable elements encode for several polypeptides that contain a number of conserved amine acid motifs, especially in the region encoding reverse transcriptase. We have used these motifs to design primers for the PCR amplification of retrotransposon DNA. These primers have allowed us to isolate a retroposon, or LINE (long interspersed nuclear element), from the pest insect, Peridroma saucia. DNA sequence analysis of this element, YAKPs1, demonstrated a high degree of homology to a number of retroposons from Drosophila melanogaster, in particular the Fw and Doc elements with homologies of up to 69%. Determination of the complete sequence of the YAKPs1 element will enable a detailed analysis of its evolutionary relatedness to other elements as well as a greater insight into its mode of action.


64. Roriz, V., L. Oliveira, and P. Garcia. 2006. Host Suitability and Preference Studies of Trichogramma Cordubensis (Hymenoptera: Trichogrammatidae). Biological Control 36, no. 3:331-336. Abstract: Studies of host suitability and preferences of Trichogramma cordubensis Vargas and Cabello (Hymenoptera: Trichogrammatidae) were performed with eggs of six Lepidoptera (Noctuidae) species: Thysanoplusia orichalcea Fabricius, Peridroma saucia (Hubner), Xestia c-nigrum L., Phlogophora meticulosa (L.), Noctua pronuba (L.), and N. atlantica (Warren). Host suitability was studied by analysing separately the effects of the attacked host species and the influence of the rearing host species on different biological parameters of T. cordubensis. Host preference was analysed by offering eggs of two host species simultaneously to a single female wasp without previous oviposition experience (dual-choice tests). Results show that P. saucia, followed by P. meticulosa were the least suitable hosts for T. cordubensis, since on these species the preimaginal development of the parasitoids was significantly longer and, the number of parasitized eggs as well the number of offspring per female were significantly lower. Contrarily, T. cordubensis parasitized at a higher rate the eggs of the endemic non-target species, N. atlantica. Dual choice tests showed that the option of the first host to be accepted by the wasp was random; however, the mean number of parasitized eggs differed significantly when two host species were offered simultaneously to T. cordubensis, always being the host species with heavier eggs the most parasitized. (c) 2005 Elsevier Inc. All rights reserved.

65. Sannino, L. 2005. Insect pests of tobacco. Informatore Fitopatologico 55, no. 2:7-10. Abstract: The more common insect pests of tobacco belong to the orders of Lepidoptera, Coleoptera and Hemiptera. The Lepidoptera noctuids Agrotis segetum and Agrotis ipsilon attack tobacco after transplant, cutting the stems at ground level. Helicoverpa armigera larvae attack buds, flowers and seed capsules of developed plants. Several other noctuids may occasionally attack plants. Small caterpillars of the Gelechiidae Phthorimaea operculella dig tunnels in leaf tissue and sometimes stems. Among the Coleoptera, Epitrix hirtipennis is the most prevalent species. Adults feed on tobacco in seedbeds and in the field, producing small round holes. The greatest damage usually occurs on wrapper tobaccos. Wireworms include some species of Agriotes that injure tobacco by feeding on roots and boring into stems of newly transplanted plants. Pentodon bidens punctatum also injures tobacco roots and stems. The aphid Myzus persicae causes damage by sucking juices from the plant and transmitting virus diseases both in seedbeds and in the field. Some minor pests such as Tipula oleracea, Thrips tabaci and Anacridium aegyptium seldom occur in damaging numbers. Stored tobacco is normally damaged by Lasioderma serricorne and Ephestia elutella. In seedbeds (float system) usually one or two treatments (thiametoxam, acetamiprid, imidacloroprid) against aphids and Epitrix hirtipennis are needed. Before transplant, a soil treatment (benfuracarb granules or phoxim) is required to control wireworms, while the use of soil fumigants is justified if nematodes are also present. After transplanting, foliar baits or sprays with pyrethroids against Epitrix hirtipennis and chlorpyrifos against Agrotis spp. are recommended. To control late-season foliar infestations of Lepidoptera (Helicoverpa armigera, Mamestra brassicae, Peridroma saucia) an application of
a pyretroid or of Bacillus thuringiensis subsp. aizawai and subsp. kurstaki is usually enough. Apart from chemical treatments, agronomical measures are needed against aphids. Monitoring of L. serricorne and Ephestia elutella adults by pheromone traps and visual inspections should be carried out for early warning. Phosphine fumigations are used to kill insects in pressed bales.

66. Satasook, C., M. B. Isman, and P. Wiriyachitra. Activity of rocaglamide, an insecticidal natural product, against the variegated cutworm, Peridroma saucia (Lepidoptera: Noctuidae). Pesticide Science 36[1], 53-58. 1992. Abstract: The dietary EC50 (effective concentration inhibiting growth by 50%) was 1.37 mg kg-1. Lethal doses causing 50% mortality (LD50) of fourth-instar larvae were 0.32 and 0.34 ?g larva-1 for topical and oral administration, respectively, based on a 96-h observation period. Mortality did not become significant until at least 72 h following administration. Rocaglamide applied to cabbage leaf discs or incorporated into artificial diet had a moderate antifeedant effect towards larvae in choice tests. Nutritional experiments with fourth-instar larvae using dietary exposure or following topical application confirmed that rocaglamide possessed both antifeedant and toxic effects. Direct assays of feeding behaviour indicated that behavioural effects could not account for the complete bioactivity observed. Significant impairment of larval growth following topical administration, concomitant with reduced food consumption, suggests that rocaglamide may act partially through central inhibition of the feeding process, leading to anorexia. -from Authors


72. Watanabe, K., W. Hara, and M. Sato. 1998. Evidence for Growth of Strains of the Plant Epiphytic Bacterium Erwinia Herbicola and Transconjugation Among the
Bacterial Strains in Guts of the Silkworm Bombyx Mori. *Journal of Invertebrate Pathology* 72, no. 2:104-111. Abstract: Growth of plant epiphytic bacteria *Erwinia herbicola* and *Pseudomonas syringae* in guts of the silkworm, *Bombyx mori*, was studied. Fifth instar silkworm larvae were fed artificial diets supplemented with these bacteria for 6 to 12 h followed by uncontaminated diets. At 1, 3, and 6 days after feeding, bacteria were isolated from insect guts and feces. A much larger population of *herbicola* was detected in the samples collected 3 and 6 days after the inoculation than in samples collected after 1 day, indicating that these bacteria grew in the insect gut, while *P. syringae* was unable to survive. Transconjugation between *E. herbicola* strains in the insect gut was also examined. First, either a donor or a recipient strain was fed to the insects in artificial diets containing the bacteria during 12 h, and then pairing strains were fed during 12 h after starvation for 12 h. The conjugative plasmid pBPW1::Tn7 was transferred into recipient cells at very high frequencies (10^{-1})/recipient after 3 days and 10^{-3} after 6 days) in insect guts. Indigenous plasmids of *E. herbicola* mobilized RSF1010 plasmid into recipient cells at frequencies of 10^{-4} in insect guts. These transconjugants were detected in the feces of the insects. Thus, plasmid-mediated gene transfer among the epiphytic bacteria in insect guts was demonstrated. The results obtained suggest that in insecta gene transfer may play an important role in the evolution of plant epiphytic bacteria. (C) 1998 Academic Press.

73. Watanabe, K. and M. Sato. 1998. Plasmid-Mediated Gene Transfer Between Insect-Resident Bacteria, *Enterobacter cloacae*, and Plant-Epiphytic Bacteria, *Erwinia herbicola*, in Guts of Silkworm Larvae. *Current Microbiology* 37, no. 5:352-355. Abstract: Five strains of *Enterobacter cloacae* isolated from several species of plants and insects were able to grow in the guts of silkworm larvae. A much larger population of *Ent. cloacae* strains was detected in the insect guts and feces collected 3 and 6 days than in samples collected 1 day after feeding artificial diets contaminating these bacteria. Furthermore, insect-origin strains of *Ent. cloacae* were mated with a donor strain, epiphytic *Erwinia herbicola*, harboring RSF1010 and pBPW1::Tn7 plasmids in the insect guts by introducing these bacteria through separate artificial diets administered at different times. A number of transconjugants, *Ent. cloacae* strains which had acquired RSF1010 plasmid, were detected from guts and fecal samples at transfer frequencies of 10^{-2} to 10^{-3} per recipient. Thus, gene transfer between epiphytic Er. *herbicola* and insect-resident *Ent. cloacae* strains in the insect guts was confirmed. These findings may provide significant information about the role of "in insecta mating" in the evolution of these bacteria.


litura (Fabr.) (Lepidoptera: Noctuidae). The extract exhibited strong antifeedant activity in a choice leaf disc bioassay with 0.18 mug cm(-2) extract deterring feeding by 50%. In nutritional assays, the crude extract reduced growth, consumption and the utilisation of ingested and digested food in a dose-dependent manner when fed to larvae, suggesting both antifeedant and toxic activities. When relative growth rates were plotted against relative consumption rates, the growth efficiency of the S. litura fed on diet containing T. americana crude extract was significantly less than that of control larvae. This result further indicates that the extract acts as both an antifeedant and chronic toxin. Toxicity is only seen following ingestion and was not observed following topical application or injection into the hemocoel. Larvae reared initially on extract-containing diet then transferred to control diet showed nutritional indices comparable to those of larvae fed continuously on control diet. This suggests that the extract is not permanently damaging the insect's digestive tract. The mode-of-action of the extract as a chronic toxin remains unknown.

76. Yongshou Xie and M. B. Isman. Antifeedant and growth inhibitory effects of tall oil and derivatives against the variegated cutworm, Peridroma saucia Hubner (Lepidoptera: Noctuidae). Canadian Entomologist 124[5], 861-869. 1992. Abstract: The substances tested are both toxic to neonate P. saucia and inhibitory to larval growth. Dietary LC50 values are 4.3, 4.7 and 5.3% fresh weight for depitched tall oil, crude tall oil, and tall oil pitch, respectively. -from Authors